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EDITED BY

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THE

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CONDITIONED RESPONSES IN ANIMALS OTHER THAN DOGS

A BEHAVIORAL AND QUANTITATIVE CRITICAL REVIEW OF EXPERIMENTAL STUDIES *

BY G. H. S. RAZRAN

Columbia University

The reader is referred to the *Archives of Psychology*, 1933, No. 148, for general criticisms of the methodology, presentation, and interpretation of the experimental work of conditioning as well as for the revised terminology used. Here it should be only added that the present review is confined to typical conditioning experiments in which both the conditioning and the conditioned stimulus are definite, different, and within the control of the experimenter, and in which the responses to these stimuli are not physically exclusive of each other. Such modifications in the behavior of an animal as occur when a spider is repeatedly stimulated by the sound of a tuning fork, an amoeba by a band of light, or when a chick swallows a caterpillar one or more times—are not reviewed here. Neither are included here experiments in the breaking of tropisms in which an original response is made to disappear by repeated subsequent applications of an antagonistic response; nor does the review deal with the much more complex discrimination experiments in which the animal is, *to begin with, simultaneously* confronted with more than one simple conditioning situation. While all these types of modifications, loosely referred by a number of writers and experimenters as conditioning, are undoubtedly related to modifications produced by typical conditioning, they are beyond the scope of this review.

* The many studies on conditioning of dogs are treated separately.

A. Conditioning of Invertebrates

Protozoa. Infusoria. A very extensive and apparently carefully controlled experiment on conditioning of colonies of infusoria, *Carchesii lachmani,* was performed by Plavilstchikov (**49**). Indeed, in number of subjects used and in time spent in experimentation, his is the most extensive single experiment in the conditioning of any organism. Eighty-two colonies were used and each colony received a few hundred combined applications of the conditioning and the conditioned stimulus at the rate of 20 combinations, with intervals of 15–20 minutes between them, per day. The conditioning stimulus was a tactile stimulation with a glass filament to which each colony responded with contraction, while as the conditioned stimulus served the réd and blue ends of the spectrum passed through colored glass filters and to which no overt original response had been observed. The apparatus, in which the infusoria were placed for experimentation, consisted of a 5 c.c. topless box pasted on the inside with black paper and mounted under a binocular microscope, from the object piece of which a black cloth overhung the top of the box. In one wall of the box was—0.5 cm. above the floor—an opening of 0.6 sq. cm. for the insertion of the colored filters, while through the other walls were protruded the handles of the glass filaments; possible tactile stimulations with the applications of the conditioned stimuli were ruled out.

All 82 colonies succeeded in forming the C–R, the magnitude of the conditioned contraction, which had been rated on a scale of 10, reaching, finally, that of the conditioning response in 51 colonies but never exceeding a fraction of the latter in the remaining 31 colonies. The number of combinations required for the first appearance of the C–R ranged from 79 to 284, with an average of 138.5 and a σ of 24.6.[1] The average for the maximum contractions was 167.95 with a σ of 23.44, while the respective V's for first and maximum contractions were 17.8 and 14.0. When the C–R was well established, parts of 43 colonies were transplanted to hosts that had previously not been experimented upon, the operation being, however, successful in only 8 of the transplantations. When the conditioned stimulus was now applied to the transplanted parts in the new colonies, contractions resulted in 1–3 trials without further training. Finally, after 7–20 applications of the conditioned stimulus and 0–4 applications of combinations of the conditioning and conditioned stimuli to the new

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[1] Unless otherwise stated, statistical measures have been computed by the reviewer.

colonies, the transplanted parts were removed and the conditioned stimulus applied to the remaining parts. Again, the C–R appeared after only 1–3 trials, thus manifesting a rather peculiar and interesting case of transfer or generalization of C–Rs.[2]

Crustacea and Cephalopoda. A series of experiments, rivaling the experiments of Plavilstchikov in extensity and by far surpassing the latter in the investigation of various phases of conditioning, were made by Mikhaïloff (**35–40**), a pupil of Bekhterev, on a number of Crustacea and Cephalopoda. 18 *Paguri striati,* 6 *Eledones moschatae,* 3 *Leander treilliani,* and 1 *Leander xiphias* were used in all the experiments on conditioning. The conditioning stimulus was throughout a tactile stimulation with an iron wire to which the Eledones responded with a chromatographic change of the appearance of shiny black patches on the back, head, and limbs of an otherwise homogeneously gray integument, and to which the other animals responded by withdrawing into their shells. The flashing of differently colored electric bulbs of 25 c.p. or the filtering of daylight through variously colored glass filters served as the conditioned stimuli, previous observations having proved that these stimuli caused no overt responses. The apparatus consisted of a glass aquarium covered with a wooden cage and with openings for the experimenter's observations and for the introduction of the conditioning and conditioned stimuli. Thirty to 100 simultaneous combinations of the conditioning and conditioned stimuli were applied daily to each animal, the intervals between separate combinations being of sufficient lengths to permit the overt disappearance of the response to the previous combinations. Simple conditioning, differential conditioning, conditioning of the second order, and, particularly, unconditioning were extensively studied. The work on differential conditioning sheds no light upon the problem of color discrimination by these animals since intensity factors have not been ruled out, but is interesting as an investigation of the characteristics of differential conditioning as such. The main data come from a very extensive

[2] Transfer of conditioning or of unconditioning is used by the reviewer when, after the formation or the unconditioning of a C–R, another C–R will be formed or unconditioned with greater ease but *not without* additional experimentation; generalization is used when some S–O–R, usually related to the conditioned or unconditioned S–O–R, becomes conditioned or unconditioned *without* additional training. In this particular case the amount of additional training was so small that the selection of the particular term cannot be made with certainty; usually, however, the two phenomena are distinct from each other and therefore the interchange of terms is confusing.

experiment on 12 Paguri, but the other studies are also of consider-
able significance and will be reviewed in the order of their presenta-
tion by the experimenter.

In the first preliminary experiment (36) 2 Paguri were used, the
conditioned stimulus being the admission of daylight through red or
green glass filters. Both animals formed the C–R, one on the 34th
and the other on the 54th combination; the response later became
well established and did not disappear until after 25 repeated
non-reinforced applications of the conditioned stimulus. One animal
also learned to differentiate between a red and red-orange filter and
the other between a green and a yellow filter.

The second more extensive experiment (37–38) was performed
on a group of Cephalopoda, 6 *Eledones moschatae,* the conditioned
stimulus being the flashing of a dull white bulb for 1 animal, a green
for 2 animals, and a red for the remaining 3 animals. All animals
formed the C–R, the number of combinations required for its first
appearance ranging from 175 to 1,112 with an average of 508; they
also were able to differentiate between bulbs of different colors, the
differential C–R first appearing as a rule 1–3 days after the simple
C–R. When the C–Rs became well established, experiments with
unconditioning were begun, using 2 intervals of 30 seconds and of
1–3 minutes between the repeated non-reinforced applications of the
conditioned stimulus for each animal on each day. These uncon-
ditioning experiments were performed on 1 animal for 2 successive
days, on another for 3 successive days, and on the remaining 2 ani-
mals (2 animals died) for 82 successive days. Their results definitely
show that the stability of the C–R—as measured by the number of
non-reinforced applications necessary for its complete disappear-
ance—decreases gradually with each successive day. Thus, for the
2 intervals the average number of non-reinforced applications for
the complete unconditioning of the C–R in the 2 animals was 10 and
28.8, 6.67 and 19.30 and 5.16, respectively 1–3, 12–14, and 23–25
days after the beginning of experimental unconditioning, while only
11 out of 320 applications of the conditioned stimulus were followed
by the C–R after 70–75 days of unconditioning. The results further
show that the longer the intervals between successive non-reinforced
applications the more trials are necessary for the unconditioning of
the C–R, but that this relationship becomes less and less pronounced
on successive days of unconditioning.

The conclusions from the results with the Cephalopoda are fully
corroborated and more conclusions may be drawn when the results

of the main experiment (**39**) on 12 Crustacea, *Paguri striati,* with daylight passed through colored glass filters as the conditioned stimulus, are closely examined. These results are presented in Table I, which is a summary of a number of the experimenter's

TABLE I

CONDITIONING, DIFFERENTIAL CONDITIONING, UNCONDITIONING, AND RECONDITIONING IN 12 PAGURI STRIATI

No. of Column	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	1	Red	56	2	1	12	25					
	2	Red	34	1	1	11	21	78				
	3	Red	47	1	1	12	22	74	202	14	12.5	21.25
	4	Green	85	3	3	8	18	27	155	19	10.0	17.75
	5	Green	104	3	4	11	19	31	179			
	6	Green	218	6	2	10	20					
	7	Or.–red	42	2	1	12	20					
	8	" "	61	2	1	10	22	78	186	11	11.75	20.25
	9	Yellow	181	5	3	10	19					
	10	Yellow	95	3	3	9	19					
	11	Daylight	591	1	0	2	4	23				
	12	"	1112	19	0	2	2					

EXPLANATION OF COLUMNS

Column   I—Number of animal.
"   II—Conditioned stimulus.
"   III—Combinations for first appearance of C–R.
"   IV—Days for first appearance of C–R.
"   V—Days of first appearance of differential C–R after simple C–R.
"   VI—Non-reinforced applications with intervals of twenty seconds.
"   VII—Non-reinforced applications with intervals of 1–3 minutes.
"   VIII—Generalization of C–R.
"   IX—Disappearance of C–R without restoration.
"   X—Reinforcements for restoration of C–R.
"   XI—Non-reinforced applications for unconditioning of restored C–R with intervals of 30 seconds.
"   XII—Non-reinforced applications for unconditioning of restored C–R with intervals of 1–3 minutes.
    ρ between columns III and VI, —0.73.
    ρ between columns III and VII, —0.72.

tables, in Table II, the entries of which have been computed from the experimenter's tables, and in curves I and II, which have been plotted from the experimenter's data. In Table I columns I and II are self-explanatory; column III gives the number of combinations before the first appearance of the C–R, while column IV shows the experi-

TABLE II

Development of Unconditioning in 12 Paguri Striati. Number of Non-reinforced Applications for Unconditioning in Periods of 5 Days

No. of animals	Days of unconditioning intervals	1–4		5–9		10–14		15–19		20–22		47, 59, 65, 78, 82	96, 113, 132, 162, 172
		30"	1–3'	30"	1–3'	30"	1–3'	30"	1–3'	30"	1–3'		
1		11.5	23	(died)									
2		11.6	22.2	7.2	19	5.4	17.4	3.6	7.2	3.0	4.0	13.8%	6.6%
3		10.6	20.6	7.6	18.6	5.6	17.6	3.2	7.6	3.34	5.0	8%	2%
4		9.0	19.0	5.8	17.6	4.4	16.0	2.4	5.4	2.34	3.0	2.2%	Disappeared on 165
5		9.4	18.8	5.4	16.6	3.8	13.0	2.2	5.6	2.0	3.0	12.8%	0.2%
6		9.6	19.0	6.5	19.0	(died on 7th day of unconditioning)							
7		11.6	19.4	7.8	20.6	5.8	17.8	4.2	8.2	(died on 21st day)			
8		10.4	22.8	6.8	19.0	4.8	16.8	3.4	7.0	2.34	4.0	16.6%	6.2%
9		9.4	18.6	(died on 6th day)									
10		9.1	18.4	6.0	17.2	3.8	13.8	2.2	5.6	2.0	3.0	(died on 49th day)	
11		1.4	2.8	0.8	1.4	0.2	0.4	0.33	(died on 18th day)				
12		1.1	2.4	0.6	1.6	0.0	0.4	0.0	0.6	(Disappeared)			

mental day on which the C–R first appeared. Column V gives the day, after the appearance of the simple C–R, when the conditioned stimulus first became differentiated from daylight passed through other filters; this differential C–R was not attained by 2 animals. Column VI gives the number of non-reinforced applications of the conditioned stimulus required for the disappearance of the
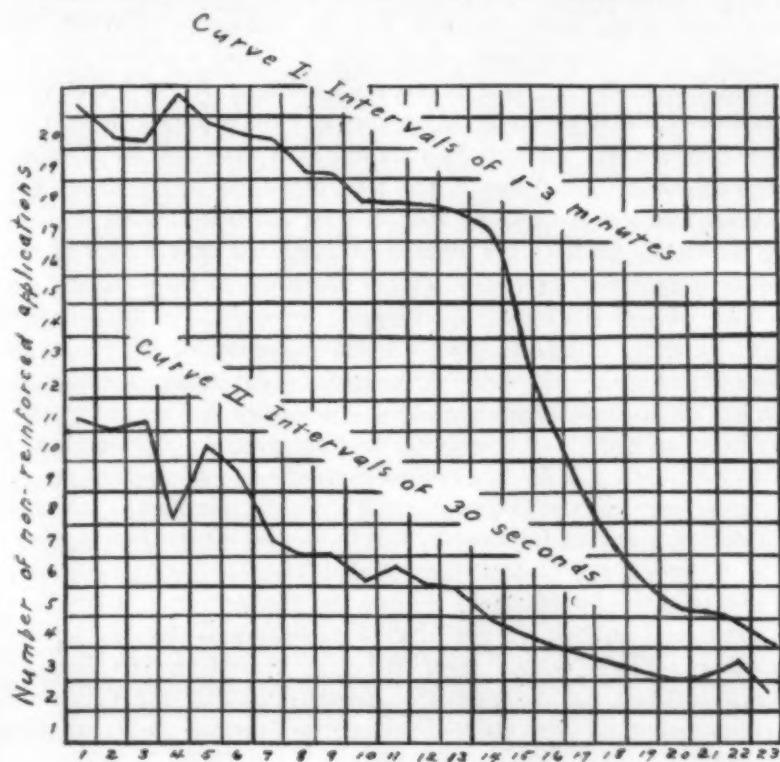
Days of Unconditioning
Figure 1. Development of Unconditioning
in 6 Paguri Striati

C–R on the first experimental day of conditioning when the intervals between repeated applications were 30 seconds; column VII tells the same about intervals of 1–3 minutes. Column VIII gives the day of experimental unconditioning on which the C–R became completely generalized (thus confirming the fact observed by many experimenters that one of the effects of the weakening of a C–R by unconditioning is its generalization); it is given only for six animals, the

remaining having died before. Column IX shows the experimental day of unconditioning on which the C–R completely disappeared without being spontaneously restored the next days; it is given only for 5 animals that survived. In 3 longer surviving animals an attempt was made to restore the disappeared C–R by reinforcing it with the conditioning stimulus, and column X gives the number of reinforced applications required for its restoration. When the restored C–R becomes well established, a second series of experimental unconditioning was begun, and columns XI and XII give respectively for intervals of 30 seconds and 1–3 minutes the average of non-reinforced applications required in 4 days for its complete unconditioning. In Table I are also given the correlations (ρ) between columns III and VI and between columns III and VII, or the correlation between the number of combined applications of the conditioning stimuli necessary for the formation of the C–R and the number of non-reinforced applications necessary for its complete unconditioning. Table II gives a detailed account of the course of unconditioning in each of the 12 animals by presenting the average number of non-reinforced applications necessary for unconditioning in successive periods of 5 days for both intervals of 30 seconds and of 1–3 minutes. In the last two columns the average percentage of the occurrences of the C–Rs are given since the conditioned stimulus was then not always followed by the C–R even on the first application. Curves I and II have been plotted from the average numbers of non-reinforced applications causing the disappearance of the C–R in the 6 best animals, in the first 13 experimental days of unconditioning. There would seem little difference—outside sluggish animals 10 and 12—between the characteristics of the curves of unconditioning of the various animals to warrant their separate plottings.

In a fourth experiment conditioning of the second order was studied in 3 Paguri. Light stimuli that had previously been found to give no overt response were associated with other light stimuli that had already been conditioned to the withdrawal response, and C–Rs of the second order were formed in all cases. One animal, which had a C–R of the first order to a red light, formed a C–R of the second order to a green light after 154 stimulations of the 2 lights. Another animal that had a C–R of the first order to an orange-red light formed a C–R of the second order to a green light after 173 combined stimulations, while a third animal formed a C–R of the second order to a red light after it had been combined with a previously conditioned green light for 197 times.

Gastropoda. An experiment on conditioning of 6 snails, Physa gyrina Say, was made by Thompson (65). The conditioning stimulus was the pressure of a piece of lettuce to the mouth region, to which the animals, as a rule, but by no means always, responded with one or more openings and closings of the mouth. As the conditioned stimulus served pressure to the upturned ventral surface of the foot to which, as preliminarily determined, the 6 animals gave responses in only 4 out of 120 stimulations. The stimuli were applied simultaneously by means of a simple apparatus consisting in the main of a rod to which had been soldered a U-shaped piece of platinum wire. One limb of the wire had been hooked for holding and administering the food while the other limb was three-pronged and turned at right angles for stimulating the foot. Each animal underwent four series of trainings. First, the conditioning stimulus was given alone for 42–60 times; this was followed by 250–253 applications of the conditioning plus the conditioned stimulus; then, the conditioned stimulus was applied alone for 17–30 times until the C–R became unconditioned; finally, 120 hours after the disappearance of the C–R, a second series of 50 combinations of conditioned and conditioning stimuli was made. Ten trials were made with each animal on each experimental day, a period of 48 hours—24 hours in which the animals were fed and 24 in which they were starved—intervening between experimental days. The results showing the percentages of stimuli followed by responses in each series are presented in Table III which is an abridgment of Thompson's tables.

TABLE III

CONDITIONING IN SNAILS, PHYSA GYRINA SAY

Number of Stimulations (first entry in each column) and Percentage of Occurrences of Food Seeking Response (second entry in each column)

Kind of Series / Number of Animal	Food alone	Food plus pressure	Pressure	2nd Series food plus pressure
4	50, 58	253, 35	17, 47	50, 86
5	50, 64	250, 24	20, 45	50, 82
6	42, 19	250, 13.2	30, 43.3	50, 32
7	50, 76	250, 32.8	20, 55	50, 72
8	60, 77.3	250, 20.9	17, 15.5	50, 88
14	60, 53.3	250, 18.8	20, 25	50, 50

In examining these results, it would seem that notwithstanding some obvious shortcomings of the experiment such as, the few trials made with the conditioned stimulus alone, the large number of times in which the conditioning stimulus was not followed by the C–R, the possibility of responses to interoceptive stimuli—all pointed out by the experimenter—there still remains some unmistakable evidence that conditioning has taken place. The rather small percentage of stimulations followed by responses in the food plus pressure series is apparently due to the interference by a strong conditioned stimulus and will become much clearer when the results of the first half of this series are compared with those of the second half as presented in Table IV. It is then seen that the percentage of stimulations fol-

TABLE IV

OCCURRENCE OF FOOD SEEKING RESPONSE TO COMBINATIONS OF CONDITIONING
PLUS CONDITIONED STIMULI

No. of Animal	First half series comb. 1-130	Second half comb. 131-230
4	22	77
5	12	50
6	1	32
7	14	64
8	4	49
14	11	

Average percentage occurrences: first half —8.2, second half —42.8.

lowed by responses in the second half is about 3–5 times as much as that of the first, the average for the 6 animals in the first half being 8.2 per cent as against an average of 42.8 per cent in the second half of the series. Such results are the rule in conditioning when strong conditioned stimuli such as loud sound or bright lights are used, and are of course also not unknown in psychological experiments in distraction and attention.

Chaetopoda. Nereidae. An experiment on conditioning of a clam worm, Nereis virens, was performed by Copeland(8). The worm was placed in an open glass tube, which was laid at the bottom of a glass dish; the dish was then filled with water and covered with a dimly illuminated box that had been provided with openings for the observations by the experimenter and for the administering of

the stimuli.   A cm. scale under the dish permitted observations of the animal's position as well as—by the aid of a stop watch—its rate of movements.   The conditioning stimulus was the placing of fragments of clam—by means of a wire—at the mouth of the tube to which the animal invariably responded with forward movements, while the conditioned stimulus was an increase of illumination by the flashing of Mazda lamps of 3.8 and 6–8 volts in the first part of the experiment and a decrease in illumination by extinguishing a Mazda lamp of 6–8 volts in the following part, the animal having been observed not to respond with forward movements to changes in illumination.   Two combinations of the conditioned and conditioning stimuli, one in the forenoon and one in the afternoon, were made each day with the animal, the conditioned stimulus preceding the conditioning by 15–20 seconds.   The C–R seems to have appeared first on the 6th combination in both experiments, and in the decrease experiments 12 further trials gave not a single failure, while in the increase experiments a month further experimentation gave only 7 failures: 5 in the first quarter, 1 in the second, 1 in the third, and none in the fourth quarter.   The latent period in the increase experiments decreased greatly from 47 to 2.6 seconds, while in the decrease experiments it was fast to begin with, ranging from 3.4 to 2.7 seconds; the rate of movement also increased.   The C–R to the increase in illumination persisted also after the decrease series and the C–R to the decrease in illumination after an intervening new set of increase experiment series.   Also, when the 2 stimuli were applied on alternate days or even in the same day, the C–R to either was retained.

Urochorda.   Ascidiacea.   Kreps (14) experimented on the conditioning of a few ascidians, using as the conditioning stimulus the falling of a drop of water on the animals from a height that could be regulated and as the conditioned stimulus the flashing of a 2-volt lamp, the sounding of an organ pipe, and the sounding of an electric bell.   The conditioning response which had been rated on a scale of 5 was either the contraction of the sphincter muscles of the animals or also the retraction of their bodies.   Four small groups of animals were used; a control group that received only the conditioning stimulus, a control group that was stimulated only with the conditioned stimulus, an experimental group in which the conditioned stimulus preceded the conditioning stimulus by 5 to 10 seconds, and an experimental group of deganglionated animals.   Evidence of conditioning was obtained only in 2 Phallusia obliqua and in 1

Steyella rustica of the normal experimental group and with the bell as the conditioned stimulus, the C–R appearing after 11–15 combinations and persisting for the 3 additional weeks of experimentation. The experimenter further adds that on cold days, when the excitability of the animals was raised, the bell elicited a response even from the control groups and that on warm days, when the excitability was lowered, even the experimental groups failed to respond but that, however, under ordinary temperature of 10–12° C. the distinction between the control and experimental groups was definite and the conditioning unmistakable.

B. Conditioning of Fish, Amphibia, and Reptila

Fish. Two simple earlier experiments on conditioning of fish were performed by McDonald and by von Frisch (10, 24). The former put 6 minnows, Pimephales notatus, in an aquarium, covered the aquarium with a cardboard, stretched a bass viol string over it, and regularly vibrated the string before dropping chopped clam meat through a small hole in the board. After two weeks of such training, the fish changed their original response of dropping to the bottom of the aquarium upon the vibrating of the string, to one of darting quickly to the surface beneath the cardboard opening. The latter, von Frisch, established a C–R in 2 small blinded catfish by whistling when the fish were daily fed with chopped clam meat. In one fish that had usually kept itself in an open tube at the bottom of the aquarium, the C–R of leaving the tube and coming up to the surface of the water upon the experimenter's whistling developed after 6 days of experimentation. It had a latent time ranging from 2 to 11 seconds and was given without failure for 30 trials following its first appearance. Another animal which, however, moved about freely, and in which evidence of conditioning was harder to ascertain, is said to have first developed the C–R after 24 trials and to have given only 4 failures and 7 doubtful responses in the following 66 trials.

Froloff's Experiments (11–13). Froloff is the first experimenter to have used a large number of fish, complex apparatus, and kymographic records of responses. His apparatus consisted of an induction coil, one wire end of which was suspended in an aquarium while the other end was attached by means of a clamp to the dorsal fin of the fish and therefrom connected with a Marey capsule and a kymograph. In the aquarium, which was in a dark room and in which, according to the experimenter, the suspended fish were swimming normally unless externally stimulated, was also submerged a tele-

phone, while above it were: an electric bell, a tuning fork, and electric lamps. Both the conditioned stimuli and the conditioning stimulus of an electric shock were activated from an adjoining room in which the experimenter and the kymograph were located, and which also had an opening into the aquarium for observation.

In the first experiment (11) only simple conditioning was studied. Three to eight combinations were made each day, the conditioned preceding the conditioning stimulus by 5–10 seconds, and the intervals between separate combinations being 2–15 minutes. The first C–R appeared after 5–30 combinations, the best results having been obtained with the submerged telephone, while the nearer the bell was to the water the faster the C–R was formed. The animals showed some original orientating response to the flashing of the lamps but not to the sounds.

In a second experiment (13), unconditioning, negative conditioning, differential conditioning, and conditioning of the second order were investigated. Both unconditioning and negative conditioning proved difficult in fish, the former requiring 20–30 non-reinforced applications for the disappearance of the C–R and the latter being impeded and always preceded by the formation of C–Rs of the second order to the extra stimulus. Similarly, differential conditioning was wrought with difficulties, although the fish finally did learn to differentiate between a red and a green bulb. On the other hand, C–Rs of the second order were easily formed and, unlike in dogs, even when the new stimulus did not precede but was given simultaneously with the conditioned stimulus. Further observations were that negative conditioning was easier when the extra stimulus was the flashing of a lamp and the conditioned stimulus a sound than when the order of applications was reversed. Also, in earlier stages of differential conditioning the application of the negative stimulus caused a decrement in the response to a subsequent application of the positive stimulus, but, when the differentiation was well established, such sequence produced an increment in the response. It is to be regretted that, outside a few single instances, the results of such an extensive and apparently well controlled experiment are neither given in detail nor represented by some statistical values. Instead, the reader is presented with general statements and conclusions on the brain mechanisms of fish which cannot be well checked up by the published data.

Bull's Experiment. A carefully controlled experiment on a number of blennies and wrasses, and on one eel was performed by

Bull (6, 7). The presentation of food or the administering of an
electric shock was the conditioning stimulus, while as successful con-
ditioned stimuli served: increases in the temperature or decreases in
the salinity of the water in which the fish were kept, changes in the
contents of the water by the admission of small quantities of clear
filtered extracts of the fish's natural food, changes in illumination
by the turning on of different lamps of various intensities and wave
lengths, sounding of an electrically driven tuning fork impinged upon
the fish aquarium, sounding of an electric buzzer enclosed in a glass
jar and submerged under water. The apparatus and the technique
for the controlled presentation of each kind of stimulus used by Bull
are very elaborate, and the reader is referred to the original report
for clear, excellent diagrams and detailed descriptions. Here will be
given only an outline of the main procedure as well as a tabular
summary and an analysis of the results. Secondary cues were appar-
ently kept out with success: the experimenter was separated from
the animals which he could observe by means of a periscope, and all
stimuli were carefully isolated and mechanically applied. The
response to the shock was recorded objectively by means of a pointer
on a floating vaselinated cover glass, while the approaching response
to food was similarly unmistakable, as it consisted either in leaving
some vessel for some feeding place or in entering some vessel to
which food was delivered. With food as the conditioning stimulus,
the conditioned preceded the conditioning stimulus by 15–30 seconds,
and about 2–5 combinations were made each experimental day; when
an electric shock was used, the 2 stimuli were given nearly simul-
taneously, intervals of about 3 minutes were made between separate
combined applications, and about 6–14 trials were performed each
experimental day.

The main results of Bull's experiments are presented in Table V.
The first and the second columns in the table are self-explanatory.
Some entries in the third column require, however, some explanation.
In the experiments with an increase in temperature as the condi-
tioned stimulus, neither the initial temperature in the aquarium nor
the increases in temperature was kept constant, the former ranging
from 6.5° to 13° C. in one fish and averaging 15.4° C. in the other, and
the latter ranging from 7.0 at the beginning to 0.4 at the end of the
experiment. With decreases in salinity as the conditioned stimulus,
the initial salinity of the water was 36–37 per 1,000 parts of water,
and the decreases ranged from 37 to 2 parts per 1,000 parts of water,
the smallest decrease that elicited a C–R being that of the 3 per 1,000

parts of water. Similarly, the changes in the contents of the water produced by the addition of 10 c.c. of filtered extract of the fish's natural food were unequal in concentration, ranging from 0.0015 per cent to 0.5 per cent, the smallest concentration producing a C–R being apparently that of 0.0075 per cent. These decreasing changes in the intensity of the conditioned stimulus were made with the intent of finding the lowest threshold of each stimulus to which the animals could be conditioned, but, of course, since the experimenter did not work long enough with one particular intensity, the characteristics of the course of the development of the C–R are thus somewhat obscured in these cases. The fourth column, which gives the number of combinations required for the first appearance of the C–R, is again self-explanatory. The fifth column presents the course of the development of the C–R after its first appearance. As a rule, when the training of the C–R was continued with a large number of com- binations after its first appearance, this development is given in per cent of positive responses in successive cycles, a cycle being the number of combinations first required to bring about the C–R. When the number of combinations after the first appearance of the C–R was small, the absolute number of positive responses and fail- ures are given, the former being denoted by plus and the latter by minus signs. This column clearly shows the gradual stabilizations of the C–R with training, in spite of the unfortunate fact that a number of failures were due to extraneous interferences. The average and the σ of the number of combinations required for the first appearance of the C–R are also given in Table V.

Bull also worked on differential conditioning with a few experi- mental animals, but it is to be regretted that he had not followed the best procedure employed in such cases in the Russian laboratories. Often, not sufficient experimentation was made with one negative stimulus before another was introduced, and in a number of cases— such as in the experiments with discriminations between color filters— differential conditioning was begun before simple conditioning was well established. However, his results would indicate that the fish differentiated more readily between the illumination of 2 electric lamps, when one lamp was unshielded and the other passed through a color filter, or when both were passed through color filters of dif- ferent hues than between unshielded illumination of widely differing intensity. Also, one of his fish readily differentiated between 1 and 2 electric lamps and another between the sounds of an electric buzzer and an electric bell, when the 2 were placed in different parts of the

TABLE V

FORMATION OF CONDITIONED RESPONSES IN FISH

No. of experiment	Name of fish	Conditioning stimulus	Conditioned stimulus	C-R First appeared	Development of C-R	Remarks
I	Blennius gattorugine Bloch	Food	Increase by 0.4-7.0 C°	43	63, 77, 90.5	
II	Blennius gattorugine Bloch	Food	Increase by 0.5-3.5 C°	9	89, 89, 89	The same fish as in experiment I
III	Blennius gattorugine Bloch	Food	Decrease in salinity by 3-37/1000	32	84.5, 100	
IV	Blennius gattorugine Bloch	Food	Decrease in salinity by 3-37/1000	18	66.67, 100	
V	Crenilabrus melops (L)	Food	Tuning fork of 128 dv.	21	76, 86, 90.5	
VI	Labrus bergylta Asc.	Food	60-watt lamp; illumination value =7500 candle meters	15	33.3, 60, 80, 86.5	
VII	Crenilabrus melops	Food	Unshielded 2-volt lamp	15	64.5, 78.5, 86	
VIII	Crenilabrus melops	Food	60-watt lamp passed through wratten filter No. 74 (green)	35	5 + 3 –	

TABLE V—*Continued*

No. of experiment	Name of fish	Conditioning stimulus	Conditioned stimulus	C-R First appeared	Development of C-R	Remarks
IX	Labrus bergylta Asc.	Food	60-watt lamp passed through wratten filter No. K3 (yellow)	23	11 + 1-	
X	Crenilabrus melops (L)	Food	60-watt + No. 70 (red)	13		Negative stimulus introduced at 16th combination
XI	Blennius gattorugine Bloch	Electric shock	60-watt lamp +No. 74 (green)	21	33.3, 71.5, 85.5	
XII	Blennius gattorugine Bloch	Electric shock	60-watt lamp +No. 70 (red)	36	25 + 2-	
XIII	Anguilla vulgaris Turton	Electric shock	Electric buzzer	31	38 + 18-	Conditioning unsuccessful with Cottus butalis, Pleuronectes platessa, and Gobius minutus
XIV	Pleuronectes platessa (L)	Food	100-watt lamp	46	59+7- Retained perfectly for 8 weeks of no experimentation	As discovered C-R existed before 46th trial in modified form
XV	Coal-fish, Gadus virens (L)	Food	100-watt lamp	19	50, 94	
XVI	Gadus callarius (L)	Food	100-watt lamp	21	75, 85, 100	
XVII	Blennius gattoragine Bloch	Food	0.001%–0.05% extract of Nereis diversicolor	10	66.7, 55.6, 55.6, 88.9, 88.9, 100	

TABLE V—*Continued*

No. of experiment	Name of fish	Conditioning stimulus	Conditioned stimulus	C-R First appeared	Development of C-R	Remarks
XVIII	Blennius gattoragine Bloch	Food	0.001%-0.05% extract of Nereis diversicolor	4	unstable: 40+30-	
XIX	Blennius gattoragine Bloch	Food	.04%	43	40+8-	38 trials with 0.1% before gave no response 0.02% = 1+ 2- 0.01 = 3+ .0075 = 7+ .00375 = 5- .0015 = 5-
XX	Blennius pholis	Food	0.5% extract of Mytilus edulis	18	22.2, 61.1, 100	
XXI	Blennius pholis	Food	0.5% extract of Patella vulgata	3	20+, then weaker solutions tried with following results: .02% = 5+ .01 = 2+ 2- .0075 = 13+ 3- .00375 = 9- .0015 = 6-	

Average number of combinations for first appearance of C-R = 22.65
$\sigma = 11.9$

aquarium. Some more of Bull's significant results not given in the table are as follows: He was unable to repeat the Froloff technique of experimenting with shock, as the fish would not stay at rest. He also was unable to confirm Froloff's results on conditioning with a submerged telephone, 109 associations with shock in one animal and a month of experimentations with another having failed to elicit a C–R; similarly unsuccessful was he with a key D on a tin whistle after 83 associations with shock. Nor did he succeed in forming a C–R to the smell of artificial substances; 10 c.c. of a suspension of 1 mgm. of artificial musk, trinitro-butyl-toluene, or of cheap soap in 1,000 c.c. of water failed to cause a C–R after 51 combinations with the conditioning stimulus of food in one, 70 in another, and 64 combinations in a third fish.

Stetter's Experiment: A very extensive investigation by the C–R method into the auditory capacity of a large number of fish was made by Stetter (**62**). However, only his studies on the formation of auditory C–Rs and their retention will be treated here, since his interesting work on auditory thresholds as such as well as his methods of finding differential thresholds by attaching two different responses to the two stimuli to be differentiated are not within the scope of this review. The noises of a rattle and of a toy pistol and a large number of musical notes ranging from A to c^6 emitted by various wind and string instruments were the conditioned stimuli, while the conditioning stimulus was the feeding or the teasing of the fish with food and the conditioning response the swimming toward the feeding place as well as the making of other preparatory food reactions. As a rule 4–6 feedings were made each day, the auditory stimuli being given a few times before and continued for some short time after the administering of the food. With the exception of 7 animals with whom the McDonald method of stretching a string over a covered aquarium was used, visual cues were kept out by destroying the animals' eyes. Disturbing extraneous noises are said to have been ruled out by the fish becoming negatively adapted to them; indeed, it is stated that the success of the conditioning was unaffected even if the experiment was performed in a hall on the second floor along the street. The C–R was formed without exception in all 59 experimental animals, the combinations required for its first appearance ranging from 3 to 35, with an average of 12.7 and a σ of 7.7 for the 49 blinded animals. After some training the C–R became very stable and was little disturbed by hunger, small changes in temperature, cleaning of the aquarium, transferring to other aquariums, and the like; its latent

period—as determined by a stop watch—is said to have been less than a second in the experimental minnows and catfish, but much slower in one loach. In 6 blinded and in the group of 10 seeing animals special tests were performed on the time that a well established C–R would be retained without experimentation, and the interesting fact was brought out that this retention ranged from 55 to 334 days with an average of 166.67 days.

Amphibia. Leutsky (15) experimented on conditioning, unconditioning, and differential conditioning in a few dozens of frogs, *Rana ridibunda.* The animals were divided into a normal group and into a group of ten whose cerebral hemispheres and lobi olfactori had been extirpated, leaving, however, the thalamus and chiasma intact. The conditioning stimulus was an electric shock which caused the frogs to leave their dark moist electrically wired compartment for another glass covered compartment which had no electric connections. The main conditioned stimulus was the turning on of an electric lamp of 120 c.p. and, since some of the animals showed some original orientating response to the light, experiments in conditioning were not begun before the orientating response disappeared by negative adaptation. Five to twelve combinations of the conditioned and conditioning stimuli were made each experimental day, the conditioned preceding the conditioning stimulus by 30 seconds, and the intervals between combinations being 2–15 minutes. The C–R appeared after 10–20 combinations, and there was no difference between the normal and extirpated animals except that the latent time of the latter to the conditioning stimulus was faster—1–2 seconds—as against 5 seconds in the former; in one animal the C–R remained unaffected by a lapse of one month of no experimentation. The process of unconditioning of well established C–Rs was, on the other hand, rather difficult and fluctuating. While the C–R could be easily made to disappear after a few days of non-reinforced applications of the conditioned stimuli, the response was readily restored and complete unconditioning without further spontaneous restoration could be attained only after a long period of experimental unconditioning. Thus, in one normal animal the C–R first disappeared on the 5th day of non-reinforced experimentation, but complete unconditioning—without further spontaneous restoration—was reached only on the 24th day of experimental unconditioning. In another extirpated animal a C–R, 7 months old, first disappeared on the 17th non-reinforced application, but complete unconditioning did not occur before the 18th day of experimental unconditioning. As the intervals between the appli-

cations of conditioned stimulus in experimental unconditioning were all equal to 2 minutes, a time C–R of the second order was soon formed in the first stages of unconditioning, the C–R appearing even if the conditioned stimulus was not given; a similar time C–R occurred also when the intervals between the combinations in the conditioning experiments were of the same lengths. Differential conditioning was studied by applying the positive stimulus 2–5 times as many as the negative stimulus, and is said to have had an uneven course of development. One normal animal learned to differentiate between a positive 120 c.p. lamp and a negative lamp of 10 c.p., the differentiation first appearing after the 11th application of the negative stimulus, but becoming stable only after the 58th application of the latter. Another operated animal gave first signs of the same differentiation on the 7th application of the negative stimulus, but the differentiation was not complete until after the 45th application of that stimulus. When the positive stimulus was applied after the negative, its latent time lengthened even if the intervals between the applications of the two stimuli were 5–15 minutes. An attempt to form an auditory C–R in frogs was unsuccessful, although sounds proved disturbing as extraneous stimuli in the conditioning experiments with lights.

Reptilia. Parschin (**48**) experimented on 5 mud-turtles, Emys orbicularis, but the results on only 2 animals are reported. The conditioning stimulus was a blow on the animals' heads by the rubber end of a lever released from a constant height, to which the animals responded by withdrawing their heads into their shells, while an electric lamp of 5 c.p. was used as the conditioned stimulus. The conditioning in the turtles took a rather long time, requiring about 200–300 combinations. Differential conditioning was also attempted and one turtle that had a C–R to a white lamp learned to differentiate it from a green lamp after 30 applications of the negative stimulus. However, differentiation between a red and a violet lamp was unsuccessful in another turtle even after 100 applications of the negative stimulus. In the first stage of the development of the differential C–R, the response to the positive stimulus was checked, if the negative stimulus was applied a few minutes before, but the C–R remained unaffected in the final stage of differentiation. Nikiforovsky (**45**), using the same technique as Parschin, reports to have formed a C–R to oil of cloves and to different time intervals of 3 and 4 minutes; the latter C–Rs are said to have been very unstable.

A rather detailed study of auditory and olfactory C–Rs in two

turtles, *Emys orbicularis,* was performed by Poliakov (52). The apparatus used was apparently the same as that of Parschin, but it is described in somewhat greater detail. A little platform bearing a lever divided into two halves of unequal weights was attached by means of Mendeléef cement to the head part of the animal's shell. One end of the lever rested upon the animal but the other, provided with a rubber end, was suspended directly over its head and could be made to strike the animal by means of the pulling of a thread. The conditioned stimuli were a large number of various odors and sounds, while the response to be conditioned was of course the animals' withdrawing their heads. Three to twelve combinations, with intervals of 1–3 minutes between them, were made each experimental day and the results would seem to confirm those of Parschin, that conditioning in turtles requires a large number of combinations. The C–R to oil of cloves first appeared in one animal after 282 and in the other after 271 combinations, and became stable after 500–600 combinations. It was very specific, stimulations of the animals with odors of turpentine, amyl acetate, and camphor eliciting no response on the first application, without additional training in differential conditioning. Similarly, an auditory C–R to a sound of 410 dv. on an organ pipe, which required 136 combinations in one and 234 combinations in another animal, was very specific at first, the sounding of a note of 165 dv. on an organ pipe, a note of 1,024 dv. on a tuning fork, and a note of 12,000 dv. on a Galton whistle causing no response on their first applications to either animal. There was, apparently, on the whole, transfer of conditioning in the same modality but not from one modality to the other. Thus, after the formation of an olfactory C–R to oil of cloves, C–Rs to other odors required only 20–30 combinations. In like manner, after the formation of an auditory C–R to a sound of 410 dv. on an organ pipe, a C–R to a note of 1,024 dv. on a tuning fork appeared in one animal only after 56 combinations. Likewise a C–R to the noise of ripe poppyseeds required—after previous auditory conditioning—only 8 combinations in one and 15 in another animal, while the speed of the formation of the auditory C–R did not seem to be affected by the presence of previous olfactory C–Rs. However, a C–R to a sound of 12,000 on a Galton whistle required 209 combinations in one and 207 in another animal—even though these animals had previous auditory C–Rs—a fact which is thought by the experimenter to indicate that turtles hear lower sounds better than higher sounds. As to unconditioning and negative conditioning, they are said to have been very easy in turtles.

C. CONDITIONING OF BIRDS AND MAMMALS

Pigeons. Popov's Experiments. A series of experiments on various phases of conditioning of pigeons have been conducted by Popov (54–57). The presentation of food or the application of an electric shock was the conditioning stimulus, while as conditioned stimuli served a variety of auditory, visual, tactile, and ampular stimulations. When a shock was used as the conditioning stimulus, the bird was placed in an especially made coat with openings for the free movements of the head and one leg only; the coat was then fixedly attached to a slanting board inside a cage, and the wires of an induction coil and of a Marey tambour and kymograph connected to the free leg. Inside the cage were also devices for the application of conditioned stimuli such as lamps, whistles, pressure apparatus, and the like, all the stimuli being of course activated from without the cage. After some time the birds are said to have become completely accustomed to this rather unusual environment, to have been restful and responsive to stimulations in usual manner. When food was used as the conditioning stimulus, it was presented in a mechanically moved container to the outside of the cage in which the birds lived freely and which rested on a system of springs enabling the registering of the animals' movements on the kymograph.

In the first experiment (54) the conditioned stimulus was largely a complete rotation of the animal in a horizontal plane, produced by means of unwinding a string on which the cage was suspended. The rotation, which is said to have been free from secondary cues, lasted for 12–14 seconds and was joined towards the end by an electric shock; about 6–15 combinations—with intervals of 3–5 minutes between them—were performed each day. Other conditioned stimuli were the sound of a whistle and tactile stimulation to the toe. In 8 out of 11 pigeons the C–R to rotation first appeared after 30–90 combinations and became stable after 120–150, but in the remaining 3 birds it did not appear even after 200 combinations. The process of the development of the C–R may be gathered from the published protocols in one pigeon that formed the C–R to rotation on the 90th combinations, on the 9th experimental day. On that day the number of responses to the applications of the conditioned stimulus was 2 out of 11; in the next succeeding periods of 5 days the proportion of responses to the number of applications of the conditioned stimulus was 7/37, 22/35, 30/38, 25/26, 26/28, 23/33, 26/30, 24/24, 20/24, 19/28, 20/23, 20/21, 29/24, 19/20. Expressed in terms of percentage of responses in succeeding cycles of 90 combinations, it

would be: 45.5 per cent, 90 per cent, 85 per cent, and 79 per cent. After the formation of C–Rs to rotation stimuli, there was apparently considerable transfer of conditioning to auditory stimuli, as the C–Rs to the latter appeared in 5 experimental pigeons after 4, 9, 6, 9, 10, and 17 combinations, while in a new pigeon 160–200 trials were required. The C–Rs usually became unconditioned after 10–20 non-reinforced applications, although some of the sound C–Rs were much more stable. A period of 20 days of no experimentation in one pigeon resulted in the complete disappearance of the C–R, but it was quickly reëstablished after reinforcement with the conditioning stimulus. A differentiation of counterclockwise from clockwise rotation was attempted in one pigeon, but, after 4 months of experimentation by the method of contrasts, it was only partially developed. Thus, in succeeding periods of 20 days of experimentation, the ratios of " no response " to the applications of the negative stimulus were: 5/24, 5/29, 8/62, 26/65, 29/60, while the ratios of responses to the applications of the positive stimulus were: 41/82, 64/98, 72/79, 85/95, respectively.

The effect of administering 2–5 c.c. of 20 per cent of alcohol upon the responses to the conditioned and conditioning stimuli was tried in 5 of the experimental birds. The alcohol was administered once, and in a few instances twice, in the middle of the experimental period, and a comparison of the responses a few minutes before and after the administering seems to show that the ampular C–R was affected most, the auditory C–R much less, but that there was no effect upon the response to the conditioning stimulus of shock. Thus, in one pigeon the ampular C–R appeared in 35 out of 37 stimulations before but only in 7 out of 40 stimulations after the alcohol was taken, while the sound C–R was present in 9 out of 11 trials before and in 13 out of 28 after the giving of alcohol; the data of the other 4 pigeons are fewer but show the same tendency. Similar results were obtained by puncturing and scrubbing clean, by means of a hooked device, the ampulae of 3 pigeons. One pigeon developed hemorrhage and lost all his C–Rs, but the results of the remaining two clearly show that only the ampular C–R was affected by the operation. Thus, in one pigeon, after the operation, the ratios of responses to stimulations were 10/112 with the ampular C–R, 78/84 with the sound C–R, and 17/19 with the tactile C–R. In the other, the ampular C–R did not appear even once in 80 stimulations after the operation, while the auditory C–R was present in 47 out of 68 stimulations.

In another experiment (55) Popov worked with 2 pigeons using the noiseless flashing of an electric lamp, preceding by one second the application of an electric shock, as the conditioned stimulus. The conditioned and conditioning stimuli were given in groups of 10 rapidly succeeding combinations, with intervals of 3–5 minutes between groups; 10–15 such groups of combinations were made daily. In one pigeon the C–R appeared first on the 34th trial and became stable after about 300 trials; in the other pigeon it appeared on the 40th trial and became stable on the 233d trial. An extra stimulus of the sound of a whistle was then introduced—0.5–1.0 second before the conditioned light stimulus—in an attempt to form a negative C–R, but the latter did not become well established, about half of 192 combinations of the extra and the conditioned stimuli having been followed by a positive response.

Negative C–Rs in pigeons were, however, successfully obtained by Bayandurov (3), a pupil of Popov. In one pigeon a C–R to a noiseless extinction of a lamp of 25 c.p. was first established, the lamp having been extinguished 3 times in each trial, and each extinction followed by an electric shock. Four to ten such trials of 3 extinctions each, were made each day, and the positive C–R appeared on the 40th trial. On the 202d trial, when the C–R became very stable reaching a height of 25 mm. on the kymograph, the extinction was preceded by the sound of a whistle and the combinations of the two repeatedly applied without the shock, while the extinction alone was always reinforced. The negative C–R then developed after 188 additional applications of conditioned and conditioning stimuli, and after a number of applications of the conditioned and the extra stimuli, the latter having been usually applied once in each experimental day. In another pigeon the C–R to the extinction of the lamp appeared on the 64th trial, became stable on the 90th trial; the sound of the whistle was introduced on the 79th trial, and the negative C–R developed on the 274th trial. In a third pigeon a C–R to an electric bell with food as the conditioning stimulus was developed after 15 combinations, a metronome was introduced as the extra stimulus, and a negative C–R was developed after 129 combinations. When the metronome preceded the bell by more than 15 seconds, a C–R of the second order to the metronome, and not a negative C–R, was formed.

In another experiment (4) Bayandurov investigated differential conditioning and " experimental neurosis " in 4 pigeons. The conditioning stimulus was the application of three successive electric shocks, while the conditioned stimulus was the noiseless exposure in

a dark room of black opaque geometrical figures—a circle, 6 ellipses,
7 polygons—on a screen illuminated by a 100 watt lamp, the intervals
between successive applications being 3–4 minutes.   All the figures
were of equal area (dimensions and axes ratios of ellipses not given)
and the pigeons had to differentiate either the polygons or the ellipses
from the circle, or the polygons from each other.   One pigeon that
first formed the C–R to the circle on the 39th trial and with which
altogether 450 trials were made, learned to differentiate the circle
from 5 different ellipses, but the differentiation broke down with the
6th ellipse closest to the circle, the bird becoming greatly excited and
losing its older coarser differentiations.   Another pigeon that first
formed the C–R on the 30th trial and with which altogether 600 trials
were made, was able to differentiate 4, 6, 8, 10, and 12-sided polygons
from the circle, but became disturbed and lost these differentiations
when an attempt was made to form a differential C–R to a 16-sided
figure.   The several polygons, however, were readily differentiated
from each other by the remaining 2 pigeons.

Recently Popov (57) attacked the problem of imitation by a
special C–R technique.   Two pigeons were placed in two adjoining
cages resting upon springboards and were stimulated by sounds,
lights, or some other stimuli known to be capable of forming a C–R.
These stimuli were, however, followed by food in only one pigeon,
while the other pigeon, which was fed at a different time and place,
could not even observe the food but only the behavior of the first
pigeon.   After a number of combinations both the unfed and the fed
pigeons showed, upon the presentation of the conditioned stimuli, the
characteristic restlessness of the food-seeking response which was
registered on kymograph.   The fed pigeon was then poisoned with
alcohol and ceased reacting to the conditioned stimuli, but the unfed
pigeon still manifested the same characteristic restlessness, appar-
ently showing that these reactions were not imitation, but C–Rs of
the second order, the C–Rs of the first order being the sight of
another bird eating.   The fact that these C–Rs of the second order
were given for months in 6 unfed pigeons without ever being rein-
forced by food, while C–Rs to the sight of food but without feeding
easily disappeared, is explained by the experimenter as due to some
special potency of C–Rs of social order.   Such an account seems to
the reviewer not only meaningless but—on the basis of the presented
data—also needless, since, as many experiments have shown, C–Rs
of the second order need not be reinforced by the first but only by
the second conditioning stimulus.   A number of other papers from

Popov's laboratory have not yet been available; in his recent summary (57) he states that he obtained differentiation of sounds and colors in normal pigeons, but could not obtain any conditioning in decorticated pigeons.

Ten Cate (64) is another experimenter who investigated a number of phases of conditioning in 2 pigeons. The presentation of food from some definite place behind a screen was the conditioning stimulus, while the food seeking response of turning towards the feeding place, waiting, picking, and the like, was observed by the experimenter through an opening. The conditioned stimuli, which were activated from behind a screen, were the sound of a metronome or of a whistle, or the flashing of an electric lamp of 50 c.p. and each stimulus lasting for 30 seconds and preceding the presentation of the food by 2–5 seconds. Five to fifteen combinations, with intervals of 3–10 minutes between them, were made each day. The C–R appeared very soon after the original defensive orientating response to the conditioned stimulus disappeared, and in a few weeks it became very stable reducing its latency from about one minute to one second. The disturbing effect of extra stimuli was found to be dependent upon the age or firmness of the C–R, the number of preceding applications of the extra stimulus, the similarity of the extra stimulus to the conditioned stimulus, and apparently also upon the general organismic effectiveness of the stimulus. Thus, the sounding of a whistle during the action of a conditioned stimulus was more disturbing—as judged from latency and extent of the C–R—when the whistle was applied on the 37th than on the 52d conditioned trial, but it was much less effective on the 22d than on its 9th application. Also, an electric bell interfered more with a C–R to a whistle than with a C–R to an electric lamp, while in general, the sound of a whistle had a more disturbing influence than that of a bell or of a trumpet. After the C–R was well established, unconditioning was rather slow, requiring about 5 hours of non-reinforced applications of the conditioned stimulus, of 30 seconds' duration each, and with intervals of 2 minutes between successive applications. When a conditioned stimulus that had not been unconditioned was applied a short time—0.5–6.0 minutes—after the application of an unconditioned conditioned stimulus, the C–R to the former was reduced, but there was hardly any effect when the intervals between the applications of the two stimuli were more than 6 minutes. Tests of retention of the C–R over a period of time of no experimentations were also made. In one pigeon a test after a week proved the C–R to be undiminished; two

weeks later, it was still present but its latent period lengthened to
34 seconds; two reinforcements brought the latency down to 7–10
seconds; 2 weeks more and the C–R was nearly gone. In another
pigeon a test after a month showed the C–R to be absent, but a few
reinforcements restored it.

Beritoff (5) experimented with one decorticated and 6 normal
pigeons using food or electric shock as the conditioning stimuli with
the normal, but only shock with the decorticated pigeon. The con-
ditioned stimuli of sounds of a metronome, or of an organ pipe, or
the flashing of an electric lamp were given for 2–10 seconds, accom-
panied by shock for 1–2 seconds or by food for 40–60 seconds, and
the behavior of the pigeons observed through an opening. Each
experimental session lasted usually for 1–2 hours, but the number of
combinations were intentionally varied from a few seconds to a few
minutes. The C–R appeared in all cases rather fast, but did not
become stable until after 200–300 combinations. It was quite gen-
eralized, and differentiation is said to have developed with great
difficulty, although one pigeon learned to differentiate a sound of an
organ pipe of Si[3] from Mi[3] and Sol[3] and partially also from La[3], after
340 trials. Another pigeon attained a differentiation of metronome
of 45 beats per minute from a metronome of 30 per minute, but not
from one of 40 beats per minute. Better results both in formation
and differentiation of C–Rs are said to have been obtained when the
intervals between combinations were 5–10 minutes than when they
were of shorter duration. Unconditioning, unlike Ten Cate's results,
is said to have been easy, requiring only 3–4 non-reinforced applica-
tions. The decorticated pigeon formed also a backward C–R, as
when the conditioned stimulus of flashing of a lamp was given a few
seconds after the conditioned stimulus of shock. Retention is said
to have lasted in the normal pigeons for a few weeks of no experi-
mentation, but only for 4 days in the decorticated pigeon.

Chickens. Zavadovsky and Rokhlina (74, 75) experimented on
conditioning and the influence of the administration of desiccated
thyroid on conditioning in 4 roosters and in 2 hens. The condition-
ing stimulus was the automatic presentation of food through one of
the two windows in the birds' coop, while the main conditioned stimu-
lus, preceding the conditioning stimulus by 15 seconds, was the sound
of a metronome of 100 beats per minute. Five to eight combinations
with intervals of 2–5 minutes between them, were made each experi-
mental day. The C–R appeared in 2–7 days and became stable at
about 10 days of experimentation. Differentiation of a metronome

of 40 beats per minute from the conditioned metronome of 100 beats per minute was attempted in three fowls but was completely and consistently developed in only one, the differentiation in the remaining two being only partial and inconsistent. When the feeding of one rooster and of one hen was changed from one window to another and the metronome of 100 beats per minute replaced by a metronome of 40 beats per minute, the C–R to the first window persisted in spite of the many feedings at the other window. However, when in another rooster, the metronome was replaced by an electric bell, the response to the old window was broken up after some experimentation. Unconditioning, tried in one rooster, did not become complete after 18 non-reinforced applications at intervals of 2–3 minutes. Also, a period of no experimentations for 11 weeks resulted in the disappearance of the differentiation, but in no case in the disappearance of the C–R. Large doses of 15–25 gm. of desiccated thyroid caused first a depression over a period of 4–5 days, during which the C–R was absent or greatly diminished, followed by a period of hyperexcitability during which the C–R was increased but the differentiation lost or greatly disturbed. Small doses of 0.05–0.5 gm. seem to have caused also an additional period of improved differentiation, and in some cases, periods of slight hyper-excitability and improvement of differentiation only. The experimenter's statements about the effect of smaller doses do not seem to the reviewer conclusive in as much as no controls were used and not sufficient data are presented to compute the reliabilities of the differences. A respiratory C–R in 6 out of 7 chicks is also reported by Watson (**69**).

Rats. The two reported short experiments on conditioning of rats make use of the animals' running towards their feeding place as the response to be conditioned. This technique was proposed as early as 1913 by Zeliony (**76, 77**), who further suggested that the path be covered with smoked paper so as to get a record not only of the time but also of the course of the running and the size of the steps. He reports that he succeeded in thus conditioning a group of rats to sound of F_2 on a tuning pipe and that as the conditioning progressed the time of reaching the feeding place became shorter, the path straighter, and steps larger, while with the development of unconditioning the processes were reversed. He also states that the animals were able to differentiate a sound of E_2 from F_2. However, nothing is mentioned about control of secondary cues, and no quantitative results are presented, so that the findings seem—in view of our knowledge of the sensory capacities of rats—extremely doubtful.

Rosanoff and Kippell (**61**) studied—what they think—the relations between the magnitude of the C–R and the intensity of the conditioned stimulus by comparing the time taken by groups of white rats to run to their feeding place upon the sound of a metronome of 160 beats per minute with varying intensities of the metronome, produced by varying its distance from the animals. This distance was 2, 4, and 6 meters respectively in 3 experimental groups of 4 rats each, while in a fourth control group only a door was opened but no metronome was sounded. Two trials were made daily and altogether 46 trials were made with each group; illuminations and sound reflections are said to have been equated. The results show that the total time for the last 23 trials was 120, 217, and 243 seconds, with medians of 5, 7, and 9 seconds for the experimental groups of 2, 4, and 6 meters distance respectively (the total time for the control group was 1,239 seconds.) Plotting these results, the authors obtain a logarithmic curve, but of course the meagerness of the data, and the failure to equate groups and to control motivations and extraneous stimulations—even from the openings of the door—hardly make the procedure worth while.

Guinea-Pigs. Upton (**66, 67**) studied auditory sensitivity in 4 guinea-pigs by the C–R method using the respiration changes produced by an electric shock to the animals' hind legs as the conditioning response and a sound of 600 dv. produced by radio oscillator, 213 as the conditioned stimulus. In each trial the conditioned stimulus was applied for 6 respiration cycles the last cycle being joined by the shock and the two stimuli terminating simultaneously. The intervals between trials were 3–5 minutes, while each experimental session lasted for one hour, and 4 sessions were made each week. The response to the conditioned stimulus was first a peculiar smoothing out of the respiration correlated with the duration of the sound, but later it was replaced by an increase in the amplitude of the respiration similar to that of the conditioning response, or—what the experimenter calls—an " end response." The " smoothing out effect " occurred in the 4 animals on the 263d, 278th, 251st, and 238th trials respectively, while the " end response " appeared respectively on the 489th, 512th, 632d, and 540th trial. A tone of 1,000 dv. did not evoke any respiration change, but a tone of 600 dv. of two differing intensities did produce the C–R.

Cats. Zeliony early reported (**78**) that his kitten was able to form a C–R of running to its feeding place to a sound of C^1 after

15 combinations; he also states that it was able to differentiate between a sound of G^1 and Fis^2, which is to be doubted as he does not mention, and apparently did not rule out, secondary cues.

Wever (70) studied the limit of hearing in 6 cats by the C–R method using respiration changes to an electric shock as the response to be conditioned and various tones produced by vacuum tube oscillators as the conditioned stimuli. The conditioned stimulus preceded the conditioning stimulus by 5 seconds, while the intervals between combinations varied, and each experimental session lasted for one hour. The experiment consisted of 3 series, and in the third series, in which the conditioned stimulus was mainly a tone of 1,024 dv., secondary cues were apparently very well ruled out. A change in respiration to the conditioned stimulus consisting of an increase in the rate and a decrease in the amplitude, named the " flutter-effect," appeared in 3 cats on the 73d, 128th, and 19th trials, and became stable on the 90th, 146th, and 69th trial respectively; in the 3 remaining cats this change occurred only in 25–30 per cent of the cases. The experimenter's contention that the changes in respiration to the tones are not C–Rs since they differ in form from the changes produced by shock are not in accord with the general sound use of conditioning in literature, which includes a number of cases in which the response to the conditioned stimulus differ in some attribute or another from that to the conditioning stimulus; furthermore, as Upton and others have shown, dissimilar changes to a conditioned stimulus may finally assume the same forms as those to the conditioning stimulus. His naming these changes a " preparatory response that we call the emotion of fear " seems a needless regression to anthropomorphism. Neither can the reviewer agree with the experimenter's placing the upper threshold of hearing at a point when the changes in respiration to the tones occur in 50 per cent of the cases. Since the probability of the occurrence of such changes is not half but very near zero, a tone that elicits respiration changes in a very small number of cases should be considered—provided secondary cues are rigidly kept out—near the threshold. The upper limit of hearing in the 3 cats would then be from the data, 20,000, 30,000, and 30,000, although it should be added that results with generalization cannot be considered as sufficient absolute evidence for thresholds and that attempts in conditioning each tone under controlled conditions should have been made.

Sheep. Liddell (16–23) and his associates have been conducting a series of experiments on conditioning of sheep in an especially built

laboratory. An early description of the laboratory and technique is given by Liddell (18). The experimenter is isolated from the animals' room which is partially sound proof. The conditioned stimuli are either auditory or tactile, given simultaneously with or preceding the conditioning stimulus by 2–10 seconds; the intervals between successive combinations are 0.5–5 minutes. In the first experiment (16, 17) a C–R was formed in 2 thyroidectomized sheep, 1 three and 1 four years old and in the normal twin of the three years old, to a tactile stimulation which was applied to the rump of the animal at the rate of 30 stimulations per minute. The C–R appeared on the 10th combination in the three years old and on the 17th combination in the four years old sheep. At the end of the 45th combination 1 mg. of thyroxin was given to the thyroidectomized sheep and the training in all animals continued until in two animals 238 combinations were altogether made, while the third, the three years old cretin, died after 1.5 months. The C–R was apparently very stable as it was elicited undiminished after a period of 6.5 months of no experimentation and unconditioning required 109 non-reinforced applications of tactile stimulations during 17 days. Thyroidectomy, the experimenter states, did not seem to have any effect on the formation and unconditioning of the C–R except for some weakenings in the periods of lethargy. In a second experiment (19) a C–R to a metronome of 60 beats per minute is reported to have been easily formed in 2 thyroidectomized sheep.

In a third experiment (20) 6 lambs were used, the conditioned stimulus being a buzzer for 2 lambs and a metronome of 120 beats for the remaining animals. The C–R appeared after 3–7 combinations and reached a stability of not being unconditioned by 11 non-reinforced applications after 18–43 combinations. It was at first generalized on the motor side involving the widespread activity of all skeletal muscles but became concentrated in the stimulated leg with training. In a fourth experiment (21) a differentiation of a metronome of 60 beats per minute from a metronome of 120 beats per minute is reported; the differentiation, however, is said to have broken down when the positive stimulus followed the negative stimulus at intervals of 2–4 minutes. In another investigation (22) the interrelation of various kinds of conditionings and the resulting disturbances in the animals' behavior, or the onset of the so-called "neurosis," was studied. The development of a delayed C–R to a metronome disturbed a perfect differentiation in a sheep between an electric buzzer and a bell at first, but with the further development of the delayed C–R, the differentiation was reëstablished. When the

intervals between the applications of the conditioned and conditioning stimulus have been prolonged to 30 seconds, the delayed C–R disappeared after some fluctuation, and the sheep became hyperexcitable for 7 months.   Similarly, disturbances, or neuroses, developed when delayed C–Rs of 5 seconds delay followed each other at intervals from 30 seconds to one and a half minutes, and, in general, upon the presentation of a long series of conditioned stimuli.   However, unlike the experiments with dogs, no sleep resulted from repeated unconditioning.

Monkeys.   Aronovich and Khotin (1, 2) studied imitation in 4 *Macacus rhesus* by a special C–R technique.   The animals, which had previously lived together, were separated so that the most aggressive animal named " The Boss," was placed in one cage and the remaining 3 animals in an adjoining cage.   Each cage was provided with 3 red and 3 blue electric lamps and separated from the other by a wooden screen during the experimental session.   Fifteen to thirty seconds after the lighting of the red lamps in one cage and the blue in the other, a door was opened permitting the animals to enter another part of the cage and obtain a pear or grapes from a covered box, which they had previously learned to uncover.   The experimenters were isolated from the animals' room, while the effect of opening the door and of other secondary cues is said to have been ruled out through long negative adaptation resulting from the many appearances of these stimuli in the absence of the lights and food.   Each day 10–12 combinations, with intervals of 4–10 minutes between them, were made, and the food seeking response appeared very soon, on the 10th combination in one cage and on the 12th in the other.   After the C–Rs in each cage were well developed, differential conditioning by the method of contrasts was begun, the animals being fed only when one kind of light was presented and food being withheld—although the door was opened—when the other kind of light was shown.   The differentiation was easily established, the animals making the food seeking response only to their positive stimuli and either not responding overtly at all to the negative stimuli or in some cases seizing the negative bulbs.   The development of the differentiation may be learned from the following: In one cage the negative blue lamps were introduced on the 26th combination, the differentiation first developed on the 33d combination and third experimental day of differentiation; the average percentage of no responses to the negative stimuli was then 50 in the next four days, 55 in the following 5 days, then 59.5 in the next 10 days, and 82.5 in the last 17 days.

After the differentiations in each cage were well established, the

wooden screen between the cages was removed, and the behavior of
the animals observed, when either 3 red or 3 blue lamps were lighted
in both cages, apparently causing a conflict between previous con-
ditioning and imitation.   The results, however, show that when the
animals were in separate cages the behavior was hardly at all affected
by imitation, the correct percentage of C–Rs for the 4 animals being:
100, 100, 100, and 86, but that when the animals were put in one
cage, the reactions of " The Boss " were followed by one animal in
50 per cent, by another in 55 per cent, and by a third not at all, while
" The Boss " followed the behavior of the others in 44 per cent of
the cases.

D. CONDITIONING AND IMMUNITY

The experiments in conditioned leucocytosis and conditioned anti-
body formation, performed on guinea-pigs, rabbits, horses, and human
beings, will be treated separately as one group regardless of the
species and order of the experimental animals used, since, at least at
the present stage, the main interest lies more in the possibility of
bringing about any immunity at all by conditioned stimuli than in
the kind of organism thus allegedly immunized.   These experiments
will also be reviewed, because of their novelty and significance, in
somewhat greater detail, although they nearly always lacked controls
adequate for such a labile response as immunity.

Metalnikov and Chorine (25–27) were the first to study the pos-
sible rôle of conditioning in immunity.   They first experimented on
conditioned leucocytosis in 24 guinea-pigs, using as the conditioning
stimuli intraperitoneal injections of tapioca, B. anthrax, or filtrates
of staphylococci, preceded by conditioned stimuli of scratching the
animal's skin or warming it with a metallic plate.   After 15–25 daily
combined stimulations of the conditioned and conditioning stimuli,
the animals were given a rest of 10–25 days to permit the peritoneal
fluid to come back to normal.   A leucocytic count of the peritoneal
fluid was then taken before, and at several intervals after, the appli-
cation of the conditioned stimuli, and the results compared with
similar tests in which the conditioning, instead of the conditioned,
stimulus was used.   Out of 24 animals, the authors state, 10 died,
10 showed conditioned leucocytosis, while 4 were unaffected by con-
ditioned stimuli.   Detailed results of 3 animals are presented.   One
animal, after 21 combined stimulations, showed an increase in the
percentage of polynuclears in the peritoneal cavity from 0.6 per cent
before the application of the conditioned stimulus, warming the skin
with a metallic plate, to 62 per cent, 5 hours after its application, as

against an increase from zero to 90 per cent when 2 c.c. of tapioca was similarly used. Another animal, after 18 combined applications of B. anthrax with scratching the skin, showed an increase in the percentage of polynuclears from zero to 41.6 per cent, the maximum increase 3 hours after the application of the conditioned stimulus, while a third animal, after 25 similar combined injections, increased the percentage of polynuclears from zero to 16.1 per cent, the maximum 24 hours after the conditioning. The effect of the application of the conditioned stimuli upon subsequent infections with mortal doses of virile germs was also studied. Six experimental animals were given the conditioned stimuli a few times and then injected with mortal doses of vibrio cholerae, while 3 control animals were administered similar doses of the germs without previous extra stimulations. As a result, all of the control but only 2 of the experimental animals died. When, a month later, 2 of the surviving experimental animals were injected with virile streptococci and the conditioned stimulus was applied prior to the injection to only one of the two animals, this animal survived while the other experimental animals died; 2 control animals died also. The evidence for conditioning is of course by no means conclusive, since—among other uncontrolled factors—the effect of the original leucocytic response to the conditioned stimuli in animals that had not been conditioned has not been determined.

The experiments on conditioned leucocytosis were also repeated by Metalnikov (27) on a group of rabbits. Each rabbit received intravenously an emulsion of vibrio cholerae that had previously been heated to 60° C., the injection being preceded by 2–3 minutes of stimulation with the sounding of a horn or the scratching of the skin. After 15–25 such daily combined injections, the experiment was suspended until the number of the leucocytes in the blood of the animals came back to normal; the conditioned stimuli were then applied, and leucocytic counts at various intervals in 48 hours taken. Out of 10 animals, 2 died, 5 are reported to have been conditioned, and 3 to have been unaffected by the conditioned stimuli. Detailed results are presented of 4 experimental animals, 2 control animals that were stimulated with the conditioned without previous combinations with the conditioning stimulus, and one control animal that received only the conditioning stimulus. One of the control animals that was stimulated with the conditioned without previous combinations with the conditioning stimulus gave a count of 4,300, 7,400, 7,200, 6,900, and 7,100 leucocytes per c.c. respectively, immediately

after, and at 3, 6, 24, and 48 hours after, the stimulations, while the other control animal had a count of 8,000 before the stimulation and 7,750, 8,100, and 7,800 at 4, 7, and 24 hours after the stimulation; the control animal that was injected with the conditioning stimulus gave a count of 2,900, 2,300, 6,700, 19,000, and 10,200, respectively, at 0.75, 3.5, 6.5, 28 and 48 hours after the injection. The changes in numbers of leucocytes per c.c. in the experimental animals were as follows: 11,600, 17,900, 16,900, and 12,200, respectively, before and at 3-5, 7, and 24 hours after the conditioning in one animal; 14,300, 28,420, 16,820, and 13,300 before and at 3-5, 7, and 24 hours after conditioning in another animal; 10,000, 24,900, 13,700, 8,700, and 8,900 at 0.25, 3.5, 6.5, 24, and 48 hours after conditioning in a third animal; 7,900, 9,500, 9,100, 15,200, and 13,700 before and at 3, 6, 24, and 48 hours after conditioning in a fourth animal. The evidence for conditioning is here again far from conclusive both because of the small number of cases and, particularly, because, as the experiment itself shows, a considerable increase in leucocytoses was observed in one control animal after the application of the conditioned without any previous combination with the conditioning stimulus.

In a third experiment Metalnikov (30) studied the possibility of conditioned antibody formation. Five rabbits were injected with 2 c.c. of dead cultures of vibrio cholerae, the injection being preceded by scratching or warming the skin of the animals. After 12-15 combined injections, an intermission of a few weeks was made, and the agglutinations titer determined before and after the application of the conditioned stimuli. Two animals died, while the remaining 3 are said to have shown conditioning. Thus, the agglutination titer of one experimental animal was 1/450 before the application of the conditioned stimulus but became respectively, 1/575, 1/625, 1/570, 1/650, 1/500, 1/375, 1/200 at successive determinations during 3 weeks after the application of the conditioned stimulus. The changes in another experimental animal were from 1/1600 to 1/1700, 1/1800, 1/2000, 1/2300, 1/1600, 1/900, and 1/800, while the titer variations in a control animal that had had no previous conditioning series were 1/200, 1/225, 1/200, 1/200, 1/175, 1/175, and 1/225 for determinations in the same periods of time. Here, too, the small number of cases, the variability and lability of the response make the results only suggestive.

Vygodchikov and Barykina (68) repeated Metalnikov's experiment on conditioned leucocytosis with 41 guinea-pigs. An experimental group received daily intraperitoneal injections of 2 c.c. of

bouillon preceded by the application of a warm metallic plate for 1–2 minutes, while a control group received bouillon alone. After 21 injections in each animal and a rest of 12 days, the conditioned stimulus was applied to the experimental, and the conditioning to the control group. The peritoneal fluid of each animal in each group was then tested before and at 0.5, 2, 5, and 24 hours after the application of the stimuli and the results of the two groups compared. The experimenters claim to have obtained conclusive evidence of conditioning, but, unfortunately, they do not present any representative statistical values for each group, nor have they ruled out the possibility of leucocytosis as an original response to the unmodified action of the conditioned stimulus by using a control group to which the conditioned stimulus alone would be applied. The leucocytic count of only two animals, one experimental and one control, are given. When the conditioned stimulus was applied to the former and the conditioning to the latter, the percentage of polynuclears reached its maximum after 5 hours in each animal and became, respectively, 75.5 and 76.5, while the percentage of monocytes reached its maximum in 24 hours and became 41.5 and 32 respectively.

Ramon and Zoeller (58) report the results of administering mixtures of antitoxins to human beings. One patient was 3 times injected with a mixture of the antitoxins of tetanus and diphtheria. When after a delay of 6 months the antitoxin of tetanus alone was given, there was a clear increase in the tetanus antitoxin, while the diphtheria immunity was not at all affected by this injection. Another patient was given two injections of a mixture of lipo-vaccine TAB plus the antitoxin of tetanus. After a year's delay the injection of the oil alone did not produce any tetanus immunity. These observations cannot of course be held as definite evidence against antitoxin conditioning, since, as the writers themselves point out, the combined injections were too few. The writers, however, state that horses, which have been injected many times with mixtures of tapioca and diphtheria antitoxin, showed no change in diphtheria immunity when only tapioca was administered.

Much more extensive experiments bearing upon the problem of conditioned immunity were performed by Ramon (59) on horses. A number of horses were injected for a number of months with the toxin and antitoxin of diphtheria. When a maximum of diphtheria antitoxins was reached, the diphtheria injections were then stopped and replaced for a few months with injections of the toxin and the antitoxin of tetanus. When the blood sera were now tested both for

diphtheria and tetanus immunity, it was found that, while the amount
of the tetanus antitoxin was high—an average of about 600 inter-
national units—the amount of diphtheria antitoxins decreased very
much, dropping in one horse from 150 to 25 units. However, when a
new injection with diphtheria was made, the diphtheria antitoxin
content went up again from 25 to 150 units. From these results the
experimenter argues that conditioning plays no part in the antitoxin
formation, for otherwise the conditioned stimuli from the tetanus
injection—needle prick, twitch, manipulation, etc.—should have pre-
vented the decrease in diphtheria immunity. That this decrease is
not due to exhaustion or interference of the two toxins or antitoxins
is thought to be proved by the fact that a new injection with the diph-
theria antitoxin brought up the diphtheria immunity again to its pre-
vious state. The reviewer, however, does not share the experimenter's
contention. In as much as the conditioned stimuli for the diphtheria
immunity were not applied alone but together with the conditioning
stimuli for the tetanus immunity, it is conceivable that the effect of
the former all went towards the strengthening of the latter, there
being a gradual unconditioning of the stimuli from the diphtheria
immunity response and a conditioning to the tetanus immunity
response. Furthermore, since there was no control group to deter-
mine the effect of the lapse of time alone upon the diphtheria
immunity, it cannot be stated with certainty that the conditioned
stimuli did not have some effect in counteracting the decrease in
diphtheria immunity.

Monari and Gelli (41) nearly exactly duplicated Metalnikov's
and Chorine's experiment on conditioned leucocytoses with groups
of cavies, but failed to find any evidence of conditioning. They used
1 experimental and 4 control groups. The experimental group
received for 2 weeks daily intraperitoneal injections of 1 c.c. of
tapioca, preceded by scratching the skin of the animals with equal
rhythm and pressure or by warming it by means of warm running
water in a glass bulb which had been kept at 50° C. 10–20 days after
the last combined injection, the peritoneal fluid for leucocytoses was
tested before the application of the conditioned stimuli, as well as
0.5, 2, 5, and 24 hours after their application. Of the 4 control
groups, one was stimulated for 15 days by daily scratching the skin
of the animals; the other group was similarly stimulated by warming
the skin; the third group received for 2 weeks daily injections of
1 c.c. tapioca and the effect of scratching the skin upon the peritoneal
fluid was tested 10–20 days after the last tapioca injection, while the

fourth group was treated in the same manner as the third except that at the end of the 10–20 days of rest warming instead of scratching the skin, was used. In no case was there observed any increase of leucocytosis after the application of the conditioned stimuli. The experimenters then attempted to check the alleged effect of conditioned stimuli upon subsequent infections with virile mortal germs. Twelve animals, divided into 1 experimental and 3 control groups, were for this purpose injected with 0.5 c.c. of Klebs-Löffler bacilli, taken from a broth culture of 48 hours. Experimental group A, of 4 animals, was injected with the virile bacilli, the injection being administered 20 days after the last combined injection of tapioca with the conditioned stimulus, and being preceded by the application of conditioned stimuli. Control group B, of 4 animals, was given the mortal injection 20 days after the last injection of tapioca alone; control group C, of 2 animals, was injected the day following its last tapioca injection, while control group D, of 2 animals, was injected without any previous extra stimulation. As a result of the injections, all the animals died: the average survival time after the injection being 38.5 for group A, 36.45 for group B, 51.65 for group C, and 35.63 for group D. This experiment would thus apparently tend to show the absence of any effect of C–Rs upon immunity, although the possibility of conditioning with a greater number of combinations, with more cases, and with better technique and control is of course not excluded.

Nicolau and Antinescu-Dimitriu (**42–44**) report a series of 3 experiments both on leucocytosis and antibody formation. In the first experiment (**42**) conditioned antibody formation was studied in 15 rabbits divided into 3 equal groups of 5 each. Groups I and II received for 3 weeks daily intraperitoneal injections of 2 c.c. of dead cultures of vibrio cholerae, preceded in group I by warming the ear of the animals with a tube of warm water at 55° C. and in group II by scratching the ear with a metallic plate for 2 minutes; group III received similar intravenous injections preceded by the sounding of a bell. Three weeks after the last injection, the conditioned stimuli were applied to 4 animals in each group—leaving the 5th as a control—and the agglutination titer of each animal taken before and 5–6 times in the course of 8–11 days after the applications of the conditioned stimuli. An increase in the titers is said to have been observed only in the experimental animals of groups I and II, but none in the experimental animal of group III. The presented results of an experimental animal in group I show an increase in titer from

1/600 to 1/1000, 1/1600, 1/1800, 1/1200, 1/900, and 1/600, while the titer values for the control animal in the same periods were: 1/600, 1/600, 1/600, 1/800, 1/800, 1/800, 1/800, and 1/800. On the other hand, the readings for the experimental animal of group III were: 1/500, 1/400, 1/600, 1/500, 1/300, and 1/300, showing variations little different from those of its control animal which were at the same periods: 1/300, 1/400, 1/400, 1/200, 1/300, and 1/200.

The second experiment (43) by the same investigators was similar in all respects to the first, except that the leucocytic count, instead of the agglutination titer, was taken before and at 6 and 24 hours after the application of the conditioned stimulus. Here again an increase in leucocytosis is reported of groups I and II, with intraperitoneal injections and after the application of tactile and thermal stimuli, but none in group III, with intravenous injections and after the giving of an auditory stimulus. Thus, the number of leucocytes per c.c. in the experimental animal of group I was 10,000 before and 15,000 and 10,000 after the applications of the conditioned stimulus as compared with a count of 9,000, 8,000, and 9,500 in the control animal, while in group III the counts were: 11,000, 13,000, and 10,000 in the experimental, and 10,000, 11,500, and 11,000 in the control animal. In a third experiment (44) 10 guinea-pigs divided into 2 equal groups were used. In the first group, injections of tapioca were preceded by warming the skin; in the second group, injections of Grassbacilli were preceded by scratching the skin. Three weeks of daily injections were followed by a 3 weeks' rest and the leucocytic counts of the peritoneal fluid taken before and at 3, 6, and 24 hours after the application of the conditioned stimuli. An increase in leucocytosis, after the conditioned stimulus had been applied, was observed in both groups. However, similar leucocytosis was also noted after the application of tactile stimuli in another group which had not previously been experimented upon, and the authors conclude that " the leucocytosis was due to the abdominal puncture for obtaining the fluid," to which it may perhaps be added " as well as to the original response to the unmodified action of the tactile stimulus."

Polletini (53) experimented on groups of rabbits. One group of 4 rabbits was administered 11 injections of typhus bacilli killed by heat, each injection being preceded by the sounding of an automobile horn for 2–3 minutes. Thirty days after the last injection the blood serum of each animal was tested for the agglutination titer, and 2 days later the sounding of the horn was applied 2–3 times in 24 hours to 2 of the 4 experimental animals, while on the following

day the titer of each of the 4 animals was again taken. The titers of 2 control animals, that had previously been given injections without any preceding stimulations, were also taken after the sounding of the horn 30 days after the last unaccompanied injection. No change in the titer is, however, reported to have been observed either in the control animals after the sounding of the horn, but the titer did increase from 1/350 to 1/200 in one and from 1/500 to 1/200 in the other experimental animal when the horn had previously been sounded. Experiments on another group of rabbits are said to have given similar results. The effect of conditioning upon anaphylaxis was then tried next. A group of 7 rabbits were injected intravenously on alternate days with 5 c.c. of a 5 per cent of beef serum, each injection being preceded by the sounding of a horn for 3 minutes. When, after the 6th injection 3 animals died, the experiment was suspended, and 15 days later the horn was sounded a few times, but no evidence of anaphylactic shock was noted. Repeating the experiment on another group of 8 rabbits and using only 2 c.c. of the beef serum and more injections combined with the sounding of the horn, gave similar results. No anaphylactic shock—tested by means of taking the pressure of the carotid, respiration, and blood coagulation—was observed after the application of the supposed conditioned stimulus.

Podkopaeff and Saatchian (**50–51**) studied conditioned leucocytosis in rabbits. Fourteen rabbits were daily injected intraperitoneally with 1 c.c. of dead staphylococci, each injection being preceded by the sounding of an electric bell for 20 seconds. After 15–18 injections, a rest of 10 days was made, and the conditioned stimulus applied 5 times during 20 minutes. The leucocytic counts of the peritoneal fluid were then taken 1.5, 3, 24, 48, 72, 96, and 120 hours after the application of the conditioned stimulus. The results which are presented in the form of a curve seem to show a decided influence of the conditioned stimulus upon the leucocytic formula.

Ostrovskaya's Experiment. By far the most careful and extensive experiment on conditioning and immunity was recently made by Ostrovskaya (**46, 47**). Forty-three experimental and 44 control guinea-pigs were used for the study of the leucocytic reaction, while 12 experimental and 11 control rabbits were investigated for agglutination titer. Each of the animals in the experimental group for the study of conditioned leucocytosis received 21 daily intraperitoneal injections of 2 c.c. of bouillon, preceded in 27 animals by warming the skin with a plate kept at 55–57° C. for 3–5 minutes, in

7 animals by scratching a definite region of the skin, and in 9 animals by applying an intermittent electric shock for 1–2 minutes to the ear. Ten to 15 days after the last combined injection, the conditioned stimulus was applied to the animals, and the leucocytic counts taken before, and 2, 5, and 24 hours after the application of the conditioned stimulus, similar counts before and after the application of the conditioning stimulus having been taken for each animal at the beginning of the experiment. Of the control animals, 18 were stimulated with the warm plate alone, 7 with scratching the skin alone, 11 were given electric shock, while 8 animals were first injected 15 times with bouillon alone and then warmed with the metallic plate; the leucocytic counts were taken at the same periods as in the experimental animals. The results, according to the experimenter, show significant changes in the leucocytic formula of the experimental group in 21 out of 27 animals after the application of the thermal stimulus, in 3 out of 7 animals after the application of the tactile stimulus, and in 5 out of 9 after the stimulation with the shock. In the control group significant changes were noted in 7 out of 18 animals that received only the thermal stimulus, in 2 out of 8 animals that received a thermal stimulus after previous injections with bouillon alone, and in 1 out of 11 animals that received the shock. Detailed data of only 7 control and 9 experimental animals are given; from these data the reviewer computed that in the animals allegedly conditioned the average increase in polynuclears, 5 hours after the application of the conditioned stimulus, was 77.6 per cent of the increase produced 5 hours after the application of the conditioning stimulus to the same animals. From the fact that the tactile stimulus caused a leucocytic change in only 1 of the 11 control, but in 3 of the 7 experimental animals, and from the further fact that, in general, 29 out of the 43 experimental animals and only 10 out of the 44 control animals showed significant changes in the leucocytic formula upon the applications of the conditioned stimuli, the experimenter concludes that she definitely established the existence of conditioned leucocytosis. The finality of such a conclusion may, however, be questioned, in the reviewer's opinion, in as much as factors other than conditioning might conceivably account for the difference between the two groups. It is possible, for instance, that the greater leucocytic effectiveness of the studied external stimuli in the experimental group was due not to conditioning but to mere repeated applications of these stimuli as well as to the greater general leucocytic responsiveness of the experimental group as a result of the many injections that it had received.

On the other hand, it is also possible that further differences between the groups would be obtained, if more than 21 combined injections were made.

For the study of conditioned antibody formation Ostrovskaya used 12 rabbits which were administered 21 daily injections of 0.5 c.c. of typhus vaccine—heated to 58° C. for an hour—each injection having been preceded in 10 animals by the sounding of an electric bell for 2 minutes and in 2 animals by the warming of the skin. The agglutination titers were then taken periodically and, when after reaching their maximums they began to decrease, the conditioned stimuli were applied and the titers again taken 5 hours, 1, 2, 3, and 4 days after the application of the stimuli. An increase in the titers after the giving of the conditioned stimuli was observed in 11 of the 12 experimental animals. However, similar titer increases upon the applications of the conditioned stimuli were also observed in 9 of 11 control animals that had previously been injected with the typhus vaccine only, and the problem of conditioned antibody formation was thus left unsolved.

An even more extensive experiment on possible conditioned antibody formation was performed by Friedberger and Gurwitz (9) on 45 rabbits divided into 3 groups of 12 and one group of 9 animals. The conditioned stimulus was in all groups the warming of the ear for 2 minutes with water heated to 60° C., while the conditioning stimulus was the intravenous injection of sheep's blood in one group, of vibrio cholerae in another, of vibrio El Tor in a third, and of typhoid bacilli in a fourth group; the doses per kg. of animal were 0.1 cm. of a 5 per cent solution of the blood and 0.1 of a loop of the dead bacteria. After 12–20 daily combinations of the conditioned and conditioning stimuli a pause of 3 weeks was made and the animals were divided into equal experimental and control sub-groups. The conditioned stimulus of warming the ear was then applied 3 times in one day to the experimental animals and the averages of the titers— taken in both the experimental and the control sub-groups 1, 3, 5–6, 7–10, 9–13, and 17 days afterwards—were computed, plotted, and compared. In 3 of the 4 experimental sub-groups the average titer values were higher than those of the controls, but the differences were small and the experimenters attribute them to chance variations, a tenable assumption in view of the fact that the antibody responses were not first equated in the sub-groups. The differences might also possibly be due to the unconditioned effect of warming the ear upon antibody formation, while, on the other hand, the possibility of

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larger differences with more experimentation and better conditioning technique is not excluded.

All the experiments on conditioning and immunity are summarized in Chart I. The box-heads in the chart are self-explanatory, but a word must be said about the " Controls Used." A number of experimenters compared the results of the experimental animals only with results of control animals that had been injected with the conditioning stimulus or with results of control animals that had received no extra stimuli before their titers or leucocytic counts were taken; certain experimenters compared the experimental results also with results of control animals to which the conditioned stimuli were applied without previous combinations with injections. The 3 kinds of entries in the " Controls Used " refer thus to the 3 kinds of comparisons. As may be seen from the chart as well as from the discussion of the results in the review, the problem of the rôle of conditioning in immunity is by no means settled. While negative results cannot of course be considered conclusive, the positive results obtained need undoubtedly further confirmations with better controls.

Conditioned Digestion Leucocytosis. Akin perhaps to the problem of conditioned immunity is the problem of conditioned digestion leucocytosis, first definitely raised by Woronoff and Riskin (71). These investigators, taking hourly counts, for 26–27 hours, of the number of leucocytes in 5 adult human beings kept from external stimulation, found that the leucocytic curve was an individual characteristic of each subject, being a function of the number and time of his habitual taking of meals. Two subjects, who ate 3 times a day, had 3 rises; 1 subject that ate 4 times a day had 4 rises, and 1, used to eating 5 times a day, had 5 rises in the curve. The taking of food caused a slight rise only, if the curve was on the decline, but had no effect when it was at its peak. When 1 subject changed his meal times for 7 weeks, the old rises in his leucocytic curve were still present, although new rises corresponding to his new meal times also began to appear. Similarly, 5 puppies, 1.5–2.0 months old, that were fed at different times, developed after 40–60 feedings rises corresponding to the time of their feeding; they also showed leucocytosis to the sight, smell, and general environment of food. The same investigators (60) made a gastric fistula in 2 dogs and compared the gastric secretions with the leucocytosis, but only 5 periods of secretions were observed in 15 periods of leucocytosis. They conclude that the variations in the leucocytic curve in adults are due to well established conditioned digestion leucocytosis, while true

CHART I

Experiments on Conditioning and Immunity

Experimenter	Response to be conditioned	Injection (conditioning stimulus)	Conditioned stimulus	Subjects used	No. of subjects (experimental)	No. reported conditioned	Controls used	Remarks
Metalnikov	Leucocytosis	Intraperitoneal. Tapioca, B. anthrax, staphylococci	Warming or scratching the skin	Guinea-pigs	24	10	Injected with conditioning stimulus. No extra stimulus applied	10 died; 4 unaffected
Metalnikov	Leucocytosis	Intravenous; vibrio cholerae	Sounding horn; scratching skin	Rabbits	10	5	Injected with conditioning stimulus. No extra stimulus applied	2 died; 3 unaffected
Metalnikov	Antibody Formation	Intravenous; vibrio cholerae	Scratching or warming skin	Rabbits	5	3	Injected with conditioning stimulus. No extra stimulus applied	2 died
Vygodchikov and Barykina		Intraperitoneal: 2 cc. of bouillon	Warming the skin	Guinea-pigs	41	Reported conditioned, but number not given	Injected with conditioning stimulus. No extra stimulus applied	
Ramon and Zoeller	Antitoxin Formation	Antitoxin of Diphtheria; Anatoxin of Tetanus	Anatoxin of Tetanus; Lipo-vaccin TAB	Human beings	2	none	Injected with conditioning stimulus	Only 3 combinations
Ramon	Antitoxin Formation	Toxin and antitoxin of diphtheria	Mechanical stimuli of injection	Horses	Not stated, apparently large number	none	Injected with conditioning stimulus	
Monari and Gelli	Leucocytosis	Intraperitoneal; tapioca, Klebs-Loeffler bacilli	Warming the skin	Cavies	Large number	none	Injected with conditioning stimulus. No extra stimulus applied. Conditioned stimulus applied without previous conditioning	
Nicolau and Antinescu-Dimitriu	Antibody Formation	Intraperitoneal and Intravenous: vibrio cholerae	Warming the skin, or scratching; sounding of bell	Rabbits	15	2 of 3 tested	No stimulus applied	No change with intravenous injection and sounding of bell

CHART I—*Continued*

Experimenter	Response to be conditioned	Injection, (conditioning stimulus)	Conditioned stimulus	Subjects used	No. of subjects (experimental)	No. reported conditioned	Controls used	Remarks
Nicolau and Antinescu-Dimitriu	Leucocytosis	Intraperitoneal and Intravenous: vibrio cholerae	Warming the skin, or scratching sounding of bell	Rabbits	15	2 of 3 tested	No stimulus applied	No change with intravenous injection and sounding of bell
Nicolau and Antinescu-Dimitriu	Leucocytosis	Intraperitoneal: tapioca, Graasbacilli	Warming or scratching the skin	Guinea-pigs	10	Control group showed same changes as experimental	Conditioned stimulus applied without previous conditioning	
Polletini	Antibody Formation	Typhus bacilli	Sounding of horn	Rabbits	4	2 in one group	No stimulus applied. Conditioned stimulus applied without previous conditioning	Other 2 experimental animals served as controls Number in other group not stated
Podkopaev and Saatchian	Leucocytosis	Intraperitoneal: staphylococci	Sounding of electric bell	Rabbits	14	Exact No, conditioned not stated	Conditioned stimulus without previous conditioning	
Ostrovskaya	Leucocytosis	Intraperitoneal: bouillon	Warming or scratching the skin, electric shock	Guinea-pigs	43	29	Injected with conditioning stimulus. Conditioned stimulus applied without previous conditioning.	10 of 43 controls also showed similar changes
Ostrovskaya	Antibody Formation	Typhus bacilli	Warming the skin sounding electric bell	Rabbits	12	Changes in experimental not different from control animals		
Freidberger and Gurwitz	Antibody Formation	Sheep's blood; Vibrio cholerae; Vibrio El Tor, Typhoid bacilli	Warming the ear	Rabbits	45	Slight differences between experimental and control animals	No stimulus applied	

digestion leucocytosis manifests itself only in the young. Szabunie-
wicz (63) experimented on 7 dogs, taking the counts at 8 A.M. and
1 P.M. When the dogs were not fed in the morning, there was no
increase in leucocytes in the afternoon, but considerable leucocytosis
appeared at 1 P.M., when the animals were fed at 8.30 A.M. After
several days of such feedings, the increase persisted with the animals
unfed in the morning, but diminished gradually in a manner similar
to the unconditioning of C–Rs, when the animals were continually
unfed in the morning. Thus, the presented results of one dog show
an increase of 30 per cent at 1 A.M. after 6 days of feeding it at
8.30 A.M. with 500 gms. of meat, but the increase diminished gradually
on successive days of not feeding the animal in the morning until it
vanished after 8 days, the average increase for the 8 days being 15
per cent. These experiments would thus attribute normal variations
in leucocytic curves mainly to conditioning. However, a most
extensive Russian study (73) of curves of leucocytosis in 5 normal
and 100 abnormal human subjects shows that these curves are neither
fully accounted for by conditioned nor by true digestion leucocytosis,
there even being indications of characteristic curves for various
abnormalities, but the general run of leucocytic curves is outside the
scope of this paper.

Summary

The main quantitative results of the experiments reviewed are
summarized in Chart II. In this chart the most complete data are on
speed of conditioning in terms of the numbers of combinations
required for the first appearance of the C–R, a fact which few
experimenters failed to report. The entries in the columns on uncon-
ditioning and retention are less complete, as, except in some experi-
ments, these phases of conditioning have not been fully investigated.
Unconditioning is given in terms of either the number of non-
reinforced applications required for the first disappearance of the
well established C–R on some experimental day, or the total number
of non-reinforced applications necessary for the disappearance of the
C–R without its further spontaneous restoration, or both; retention
is given usually in terms of the number of days the C–R has been
retained without further experimentation. When the numbers are
separated by commas, the results are for individual subjects; when
by dashes—the results are for the entire group. The entries in the
column on special phases of conditioning do not give any quantitative
results but merely indicate what particular special phases of con-
ditioning have been observed in particular experiments.

CHART II
CONDITIONING IN VARIOUS ORGANISMS

Name of organism	Experimenter	No. of subjects	Conditioning stimulus	Conditioned stimulus	Combinations for conditioning			Non-reinforced applications for first unconditioning	Unrestored unconditioning	Retention	Special phases of Conditioning
					Range	Average	S. D.				
Protozoa. Carchesii lachmani	Plavilstchikov	82	Tactile	Light	79-284	138.5	24.6				
Crustacea. Paguri striat	Mikhailoff	14	Tactile	Light	34-1112	503		2-25	20, 155, 179, 186, 202 days (each day-1-25 applications)		Differential conditioning, conditioning of second order, negative conditioning
Cephalopoda. Eledone moschate	Mikhailoff	6	Tactile	Light	175-912	508		6-20	81 days (1-20 per day)		Differential conditioning
Chaetopoda. Nereis virens	Copeland	1	Chemical food at some distance	Light		6					
Urochorda. Ascidiea	Kreps	3	Tactile	Sound	11-15					One month	
Fish	Froloff	Large no.	Electric shock	Lights and Sounds	5-30			20-30			Differential and negative conditioning, conditioning of second order
Fish	Bull	21	Electric shock; food	Various	3-46	22.65	11.9			3 weeks	Differential conditioning
Fish	Stetter	59	Food	Sounds	3-35	12.7	7.7			55, 98, 138, 149, 190, 229, 334 days	
Frogs. Rana esculenta	Leutsky	Few dozens	Shock	Lights	10-20			5 days 17 applications	24 days 18 days	one month	Differential conditioning, conditioning of second order, long after effects

CHART II—*Continued*

Name of organism	Experimenter	No. of subjects	Conditioning stimulus	Conditioned stimulus	Combinations for conditioning			Non-reinforced applications for first unconditioning	Unrestored unconditioning	Retention	Special phases of Conditioning
					Range	Average	S. D.				
Reptiles. *Emys orbicularis*	Parshin, Poliakov	7	Blow on head	Lights	200-300			a few times			Differential and negative conditioning, long after-effects, transfer within same modality
Pigeons	Popov, Bayandurov	13	Shock; Food	Lights; Sounds; Rotation	30-40			10-20: some much longer			Differential and negative conditioning, conditioning of second order, transfer from rotation to sounds
Pigeons	Ten Cate	2	Food	Lights; Sounds	Fast			5 hrs. 100-200 applic.		a few weeks	After-effects of 6 minutes
Pigeons	Beritoff	7	Food; Shock	Lights; Sounds	Fast, but stable at 200-300 combinations			3-4 times		a few weeks	Differential conditioning
Chickens	Zavadovsky	6	Food	Sounds	12-40			18 applications		11 weeks in all subjects	Differential conditioning
Guinea-pigs	Upton	4	Shock	Sound	238-263						
Cats	Wever	3	Shock	Sound	19-128						
Sheep	Liddell	11 (estimated)	Shock	Sounds; Tactile	3-17			109 applications over 17 days (not clear what type of unconditioning)		6.5 months	Differential and delayed conditioning
Monkeys. *Macacus rhesus*	Aronovich and Khotin	4	Food	Lights	10-12						Differential conditioning

Conclusions

The data presented in the chart and in the text of the review offer both a phylogenetic comparison of the characteristics of conditioning in the various organisms and a check upon the generalizations of conditioning current in the literature. The phylogenetic comparison is doubtless greatly obscured by the fact that neither the stimuli involved in the conditioning nor the conditions of their applications have been by any means equal in the various organisms conditioned. It is, however, the best present evidence on the relation of a most significant form of modifiability, or learning, to the complexity of an organism, or its position in the evolutionary scale. The checking of generalizations of conditioning as such—irrespective of the organisms conditioned—is much less subject to confusion with extraneous factors. For convenience, the conclusions from the data will be taken up severally under the different phases of conditioning.

Simple Conditioning. 1. Typical conditioning, in which an inadequate stimulus for some response has become adequate by virtue of its association with an adequate stimulus, has been clearly demonstrated in a large number of cases in organisms as low as infusoria.[3]

2. There is no evidence that the speed of conditioning, measured by the number of combinations required for the first appearance of the C–R, becomes *consistently* greater with the ascent of the organism in the evolutionary scale.

The speed of conditioning of fish, ascidians, and frogs does not differ from that of dogs, sheep, monkeys, and children. Conditioning in reptiles is slow, but whether it is due to the nature of the animal or to the ineffectiveness of the particular stimuli used is unknown. On the other hand, the rather uniform slow conditioning of crustacea, cephalopoda, and infusoria as well as the fact that slow conditioning in dogs and, particularly, in young children goes as a rule with retarded intelligence or behavior would suggest that the nature of the organism does play some rôle in the readiness of the formation of C–Rs.

3. After its first appearance and before its final constant establishment in the organism, a C–R passes through a transitional period of instability during which the frequency of the occurrences of the response is low, the magnitude smaller, and the form sometimes different from that of the final C–R.

This is evidenced from the experiments of Plavilstchikov, Bull,

[3] Reported modifiabilities in the behavior of amoeba, stentor, and paramecium are not cases of typical conditioning.

Popov, Beritoff, Upton, and many others; indeed, the existence of a transitional period leads experimenters to specify not only the number of trials required for the first appearance of the C–R but also for its final stabilization.

4. There is some evidence that, with the same stimulus applied to a group of animals, the correlation between the lengths of the periods of experimentations before the first appearance of the C–R and the lengths of the transitional periods is negative.

This negative correlation is indicated by the fact that the σ and " V " for maximum contractions is smaller than that for the first appearance of the C–R in 82 infusoria. No other similar experiment with the same stimulus applied to a large number of other animals has been made to check the reliability of this generalization as well as its universality in the animal kingdom.

Unconditioning. 1. C–Rs may become so firmly established that 100 or more non-reinforced applications are necessary for their disappearance.

This is concluded from the experiments of Mikhaïloff, Liddell, Leutsky, and Ten Cate. It is to be regretted that the objection often raised by American writers against the importance of the C–R as a unit of learning is that the C–R is very unstable, disappearing after a few non-reinforced applications. This blunder has apparently arisen from a superficial consideration of the salivary C–R which is as a rule the most easily unconditioned response, but even the salivary C–R becomes readily restored in a few hours, and the total number of non-reinforced applications for its unrestored unconditioning is ordinarily many, many times more.

2. There is no convincing evidence that the speed of unconditioning is related to the phylogenetic position of the organisms unconditioned.

Unconditioning in crustacea, cephalopoda, fish, and frogs is apparently as a rule somewhat slower than that in higher organisms, but it is impossible to say, at the present state of research, whether this is due to the lesser plasticity of these lower organisms or to the many other unequated factors upon which the rate of unconditioning depends.

3. The evidence for the correlation between the speed of conditioning and speed of unconditioning is contradictory.

In 12 crustacea, a ρ of —0.73 has been obtained between the speeds of conditioning and unconditioning; unconditioning was also very fast in turtles where conditioning was slow. In children, how-

ever, Mateer obtained a positive correlation, while other experiments on children as well as experiments on dogs indicate positive correlations in some cases and negative in others. A plausible supposition for the contradictory results would perhaps be that this correlation is largely determined by the two opposing factors. On the one hand, greater plasticity that causes an organism to become more readily conditioned would apparently also induce readier unconditioning, but, on the other hand, a C–R in more plastic organisms may also be supposed to be more firmly established and thus less readily unconditioned.

4. In an extensive study on crustacea, the curve of unconditioning, measured by the number of non-reinforced applications required for unconditioning in successive days, was found to be on a whole negatively accelerated, while—with the exception of the last few days—the decrement of unconditioning was 2–4 times smaller when the intervals between successive non-reinforced applications were 1–3 minutes than when they were 30 seconds.

This curve was obviously determined not only by the decrement of the C–R caused by unconditioning but also by that of time as well as by the increment produced by spontaneous restoration. It is, however, the kind of unconditioning that is more likely to occur in behavior of organisms under natural non-experimental conditions.

Retention. 1. C–Rs have been found to be retained over periods of 2–11 months of no experimentation in lower organisms.

The results are not to be considered the limits of retention time nor are they sufficient to warrant any statement about the relation of retention of C–Rs to the organisms conditioned.

Special Phases of Conditioning: Differential and Negative Conditioning, Conditioning of the Second Order, Transfer, Long After-effects.

1. Existing evidence does not warrant any conclusion about consistent qualitative relationships between special phases of conditioning and the phylogenesis of the organisms conditioned.

Whenever attempted, these phases have been observed in lower as well as in higher organisms, in crustacea and in fish as well as in dogs and in children. Reported differences in these phases between various organisms by some Russian experimenters and their attempts to classify animals according to types of nervous systems, or the amount of " inhibition," " excitation," and ratio of " inhibition " and " excitation," is apparently due to a confusion of sensory capacities with brain mechanisms. Thus, the fact that a fish or a frog does

not differentiate between lights of differing intensities as well as a dog or a monkey need not be due to differing amounts of " differential inhibition " but to differences in sensory capacities. Similarly, the possible differences in negative conditioning, or when a fish finds more difficulties than a dog in responding to a light plus a sound differently than to a light alone are probably also due to differences in capacities and not to differing amounts of " conditioned inhibition." [4]

Conditioning and Immunity: 1. The positive evidence for conditioned immunity is suggestive but not conclusive and more experiments under more controlled conditions are needed for its definite establishment.

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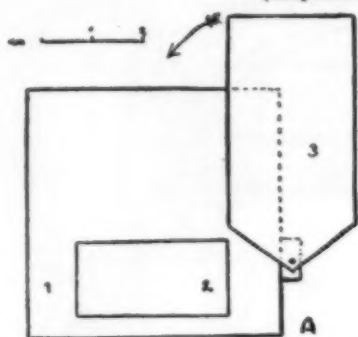## DIAGRAMS OF APPARATUS
(Explanations in Text)

Fig. 1, A. 1—la paroi antérieure.
2—la fenêtre.
3—le verre absorbant mobile.
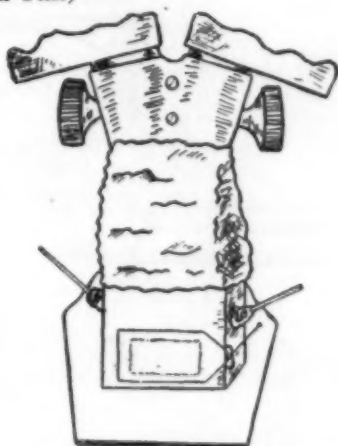
Fig. 2. Vue générale de l'appareil.
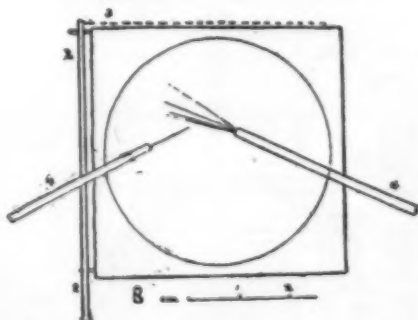
Fig. 1, B. 1—la coupe.
2—la manche de la charnière du verre absorbant.
3—le verre absorbant.
4—les manches avec les fils de verre.
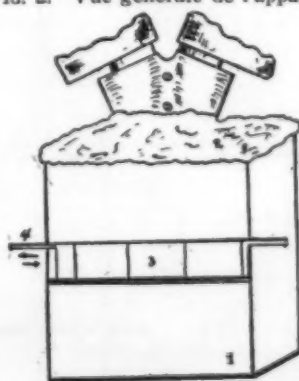
Fig. 3. L'appareil pour les expériences de controle.
1—la boite.
2—l'étoffe noire.
3—la fenêtre.
4—le verre absorbant mobile.

Fig. 2. Plavilstchikov's Apparatus for Conditioning of Infusoria, *Carchesium lachmanu.*

From Russky Arkhiv Protistologii, 1928
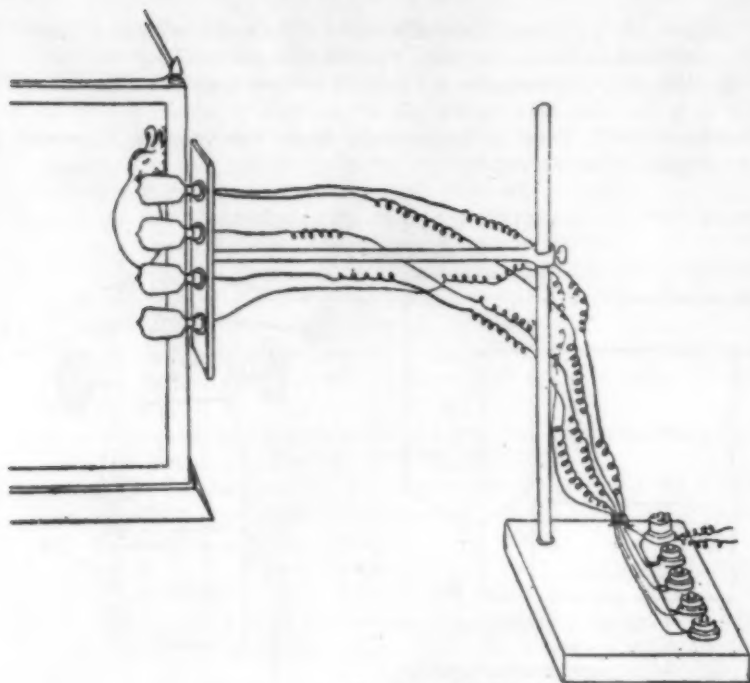
Courtesy of Bulletin de l'Inst. Oceanographic

FIG. 3. Mikhaïloff's Apparatus for Conditioning of Cephalopoda, *Eledone moschata.*
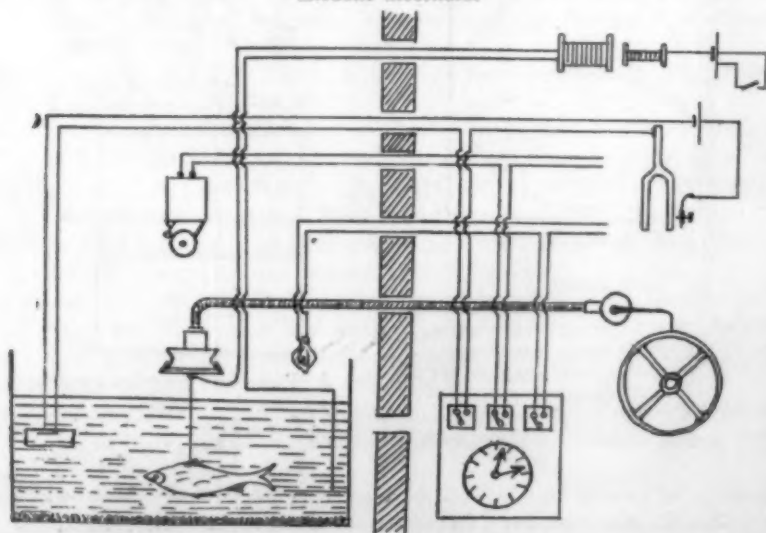
Courtesy of Pflügel Arch. f. Physiologie

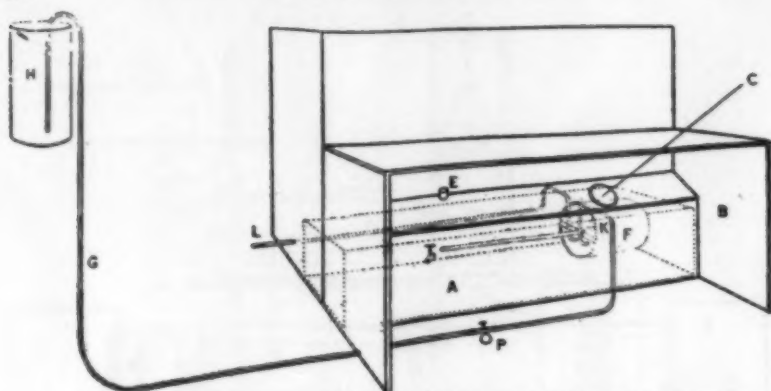Froloff's Apparatus for Conditioning of Fish.
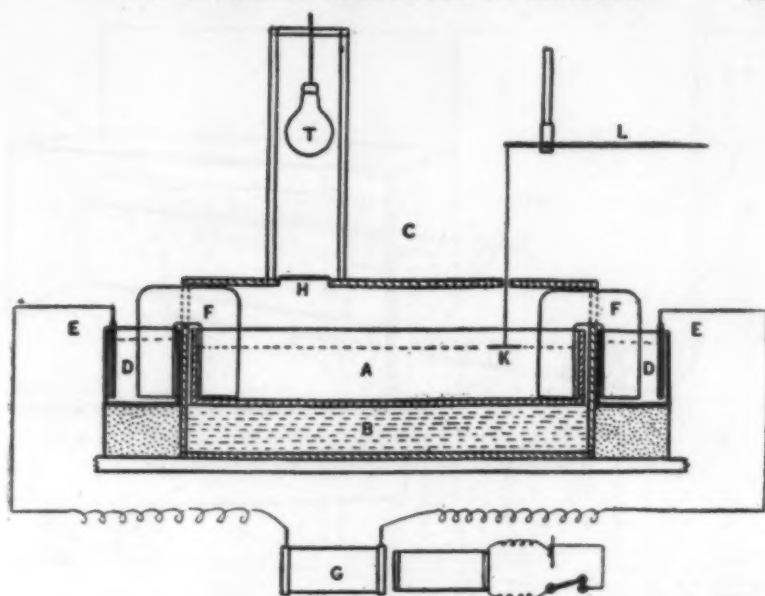
Courtesy of Marine Biol. Asso. United Kingdom

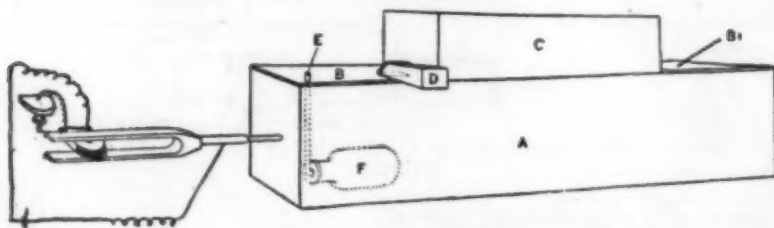FIG. 4. Bull's Apparatus for Conditioning of Fish with Shock as Stimulus.
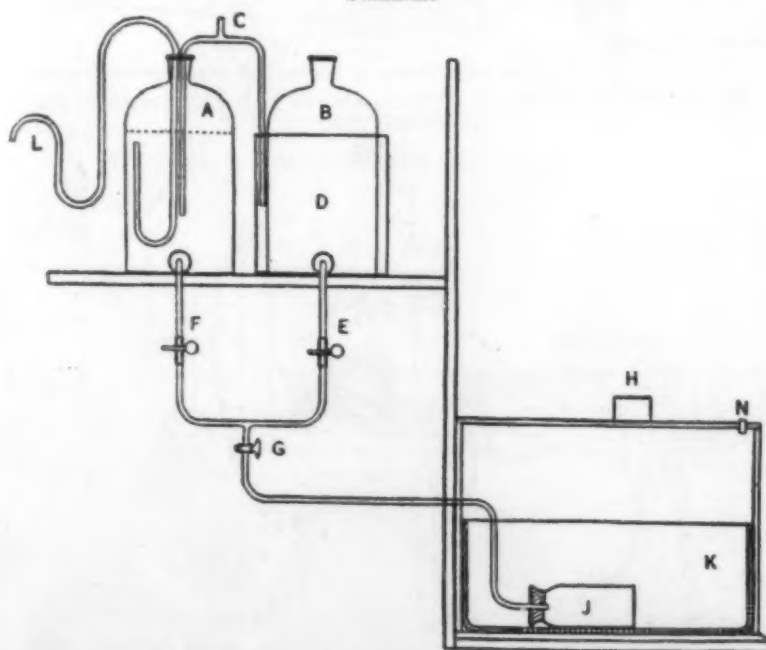
Courtesy of Marine Biol. Asso. United Kingdom

FIG. 5. Bull's Apparatus for Conditioning of Fish with Changes in Salinity as the Conditioned Stimuli.

FIG. 6. Bull's Apparatus for Conditioning of Fish with Changes in
Temperature as the Conditioned Stimuli.

FIG. 7. Bull's Apparatus for Conditioning of Fish with Sounds as the
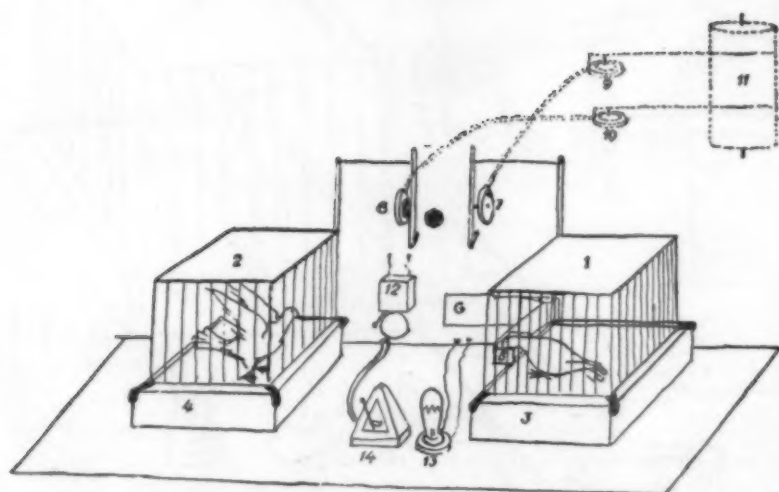Conditioned Stimuli.

FIG. 8. Popov's Apparatus for Conditioning of Pigeons with Shock as the
Conditioning Stimulus.
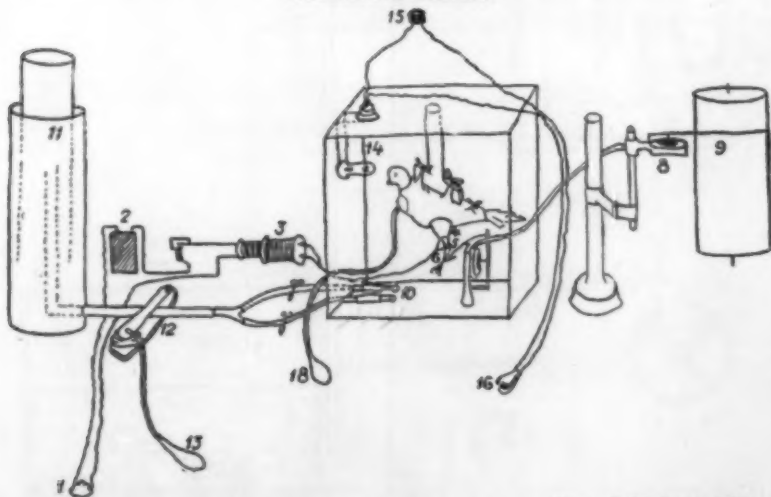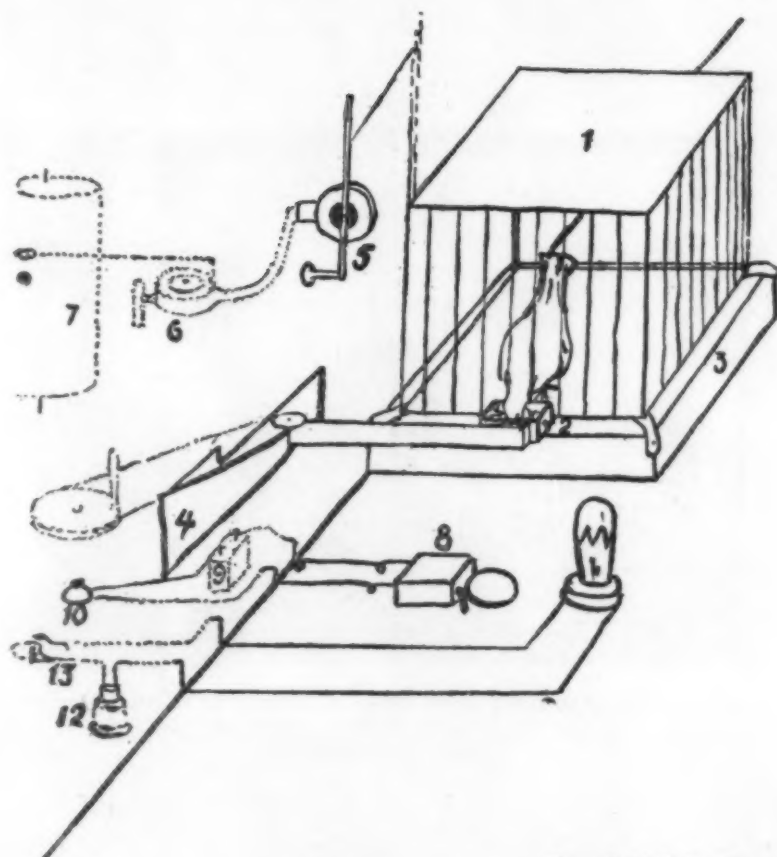
From Psikhologia, 1930

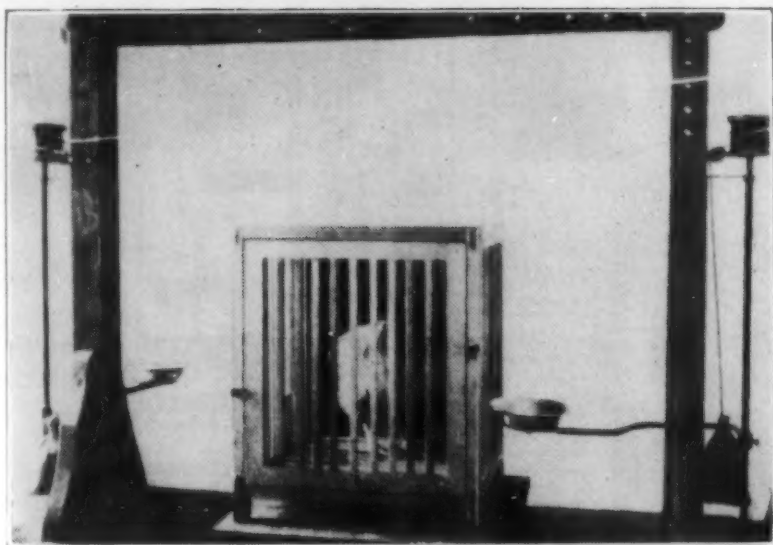Fig. 9.   Popov's Apparatus for Conditioning of Pigeons with Food as the
Conditioning Stimulus.

Fig. 10. Popov's Apparatus for the Study of Imitation by a C–R Technique.

From Med. biol. Zhurnal, 1929

FIG. 11. Zavadovsky's Apparatus for Conditioning of Chicks with Food as
the Conditioning Stimulus.

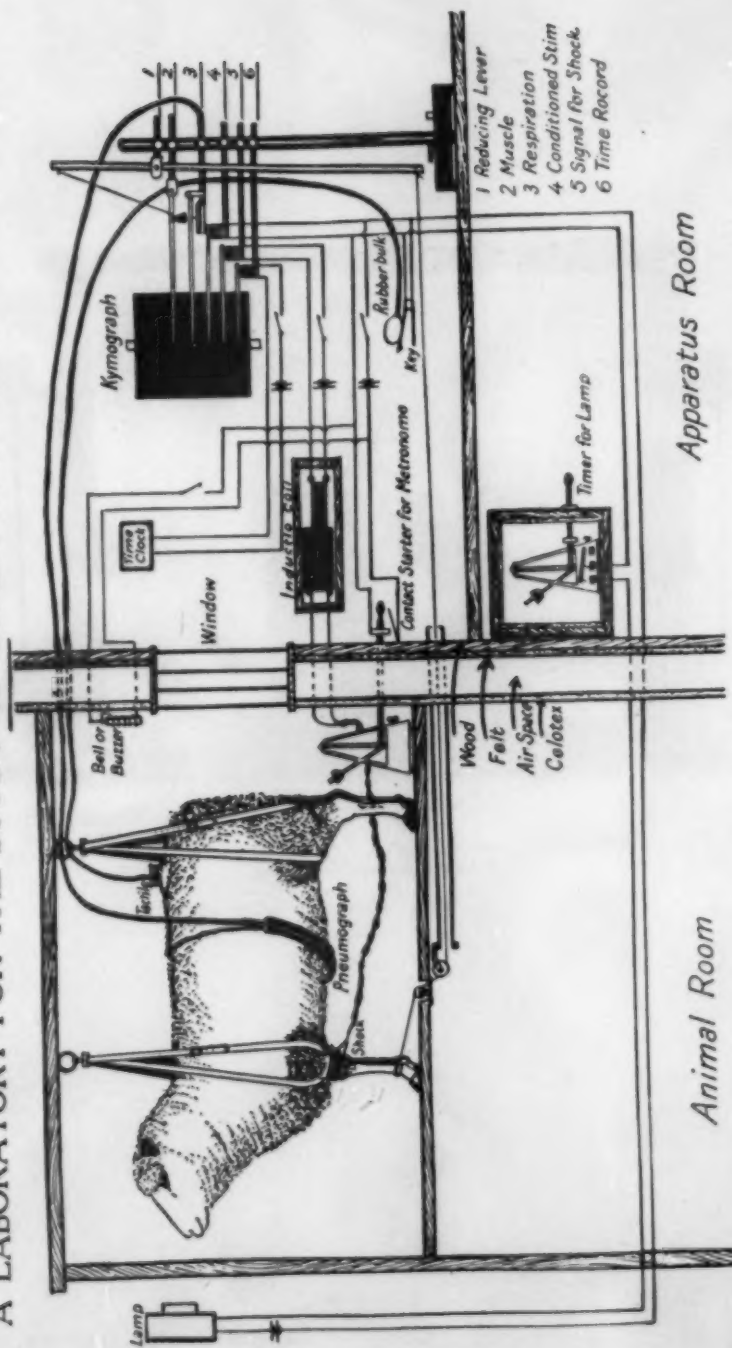# A LABORATORY FOR THE STUDY OF CONDITIONED MOTOR REFLEXES

Drawing by B. K. Macmillan

Courtesy of H. S. Liddell

Fig. 12

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